Rapid Sand Filtration: Laboratory Analysis and Profiling

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City of Dayton

CITY OF DAYTON water one source
Regional • Reliable • Renewable

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Background

- Water Bacteriologist-Chemist
  - Water Quality Laboratory
- The City of Dayton Water Department serves 400,000 people
  - City of Dayton
  - Montgomery County
- Pump 60-80 MGD
- Two water treatment plants
  - Lime softening and Cl disinfectant
- Ground water under the influence of surface water
- Lime Reclamation Facility

Overview

- Plants
- Filters- Types and Purpose
- Rapid Sand Filters- Materials
- Filter Rebuilding
- Filter maintenance and washing
- Filter Profiling
- Filter Analysis
- Profile results

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Miami WTP

- Built in 1965
- 16 Rapid sand filters
- 8 filters added in: 1983
- Filters last replaced: 2016
- Each filter: 44’ x 36’-8”
- Upflow clarifier

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Ottawa WTP

- Built in 1953
- 16 Rapid sand filters
- Filters last replaced: 2009
- Each filter: 44’ x 36’ -8”
- Rectangular sedimentation basins

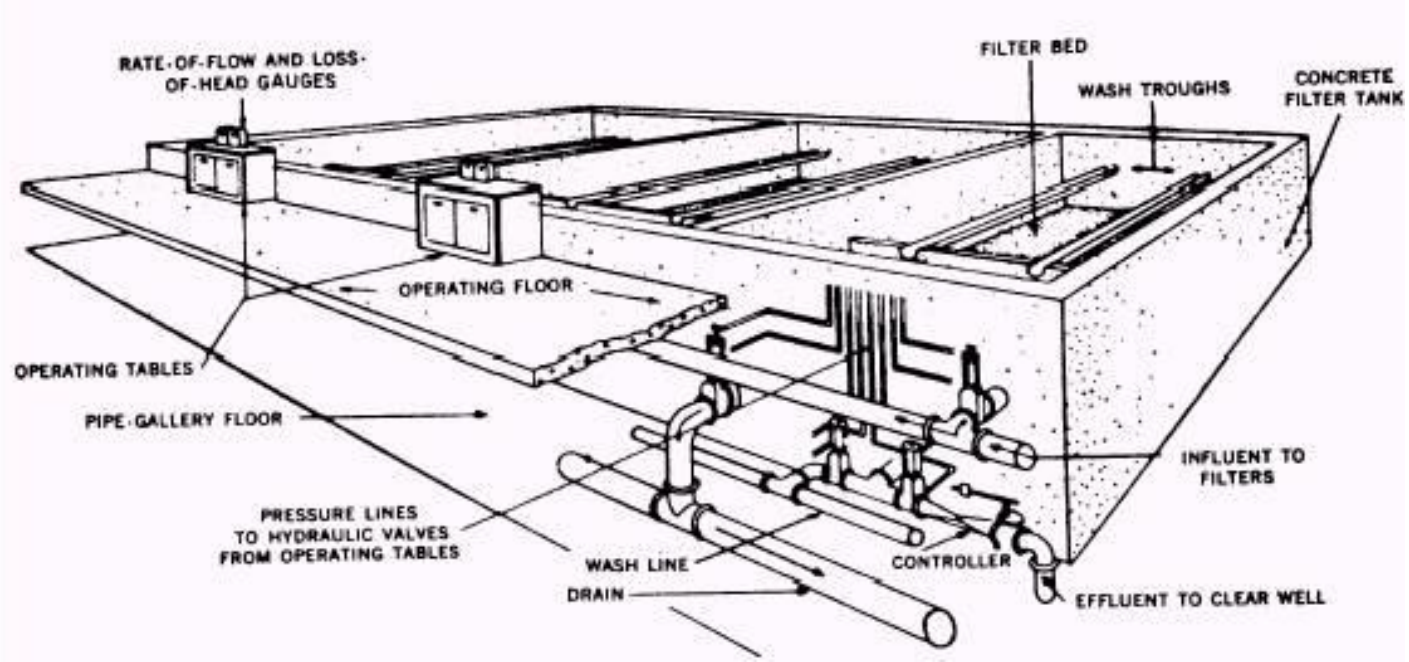
Water Filtration

- Types of Filtration
- Purpose
- Process
- Media

Types of Filters

- Gravity vs Pressure
- Convetional vs Direct
- Rapid vs Slow

- Dayton's Filters: Gravity-Conventional-Rapid

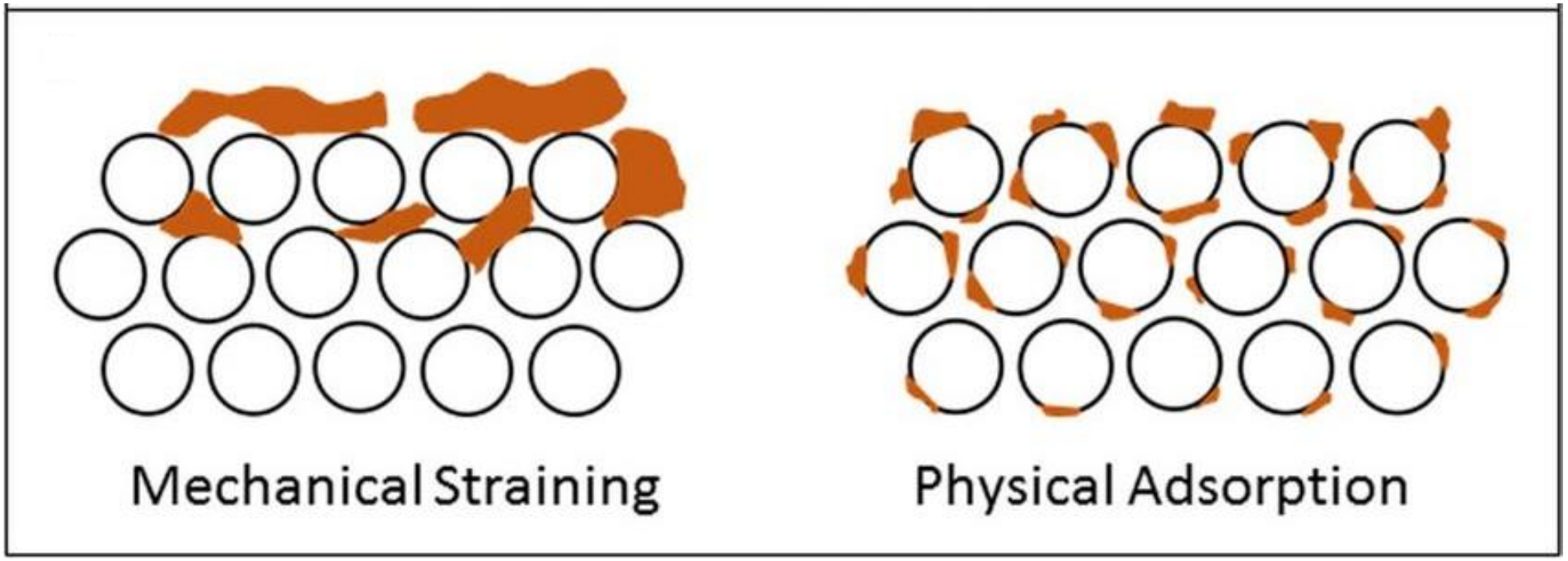


Purpose

- Remove suspended matter
- Remove turbidity

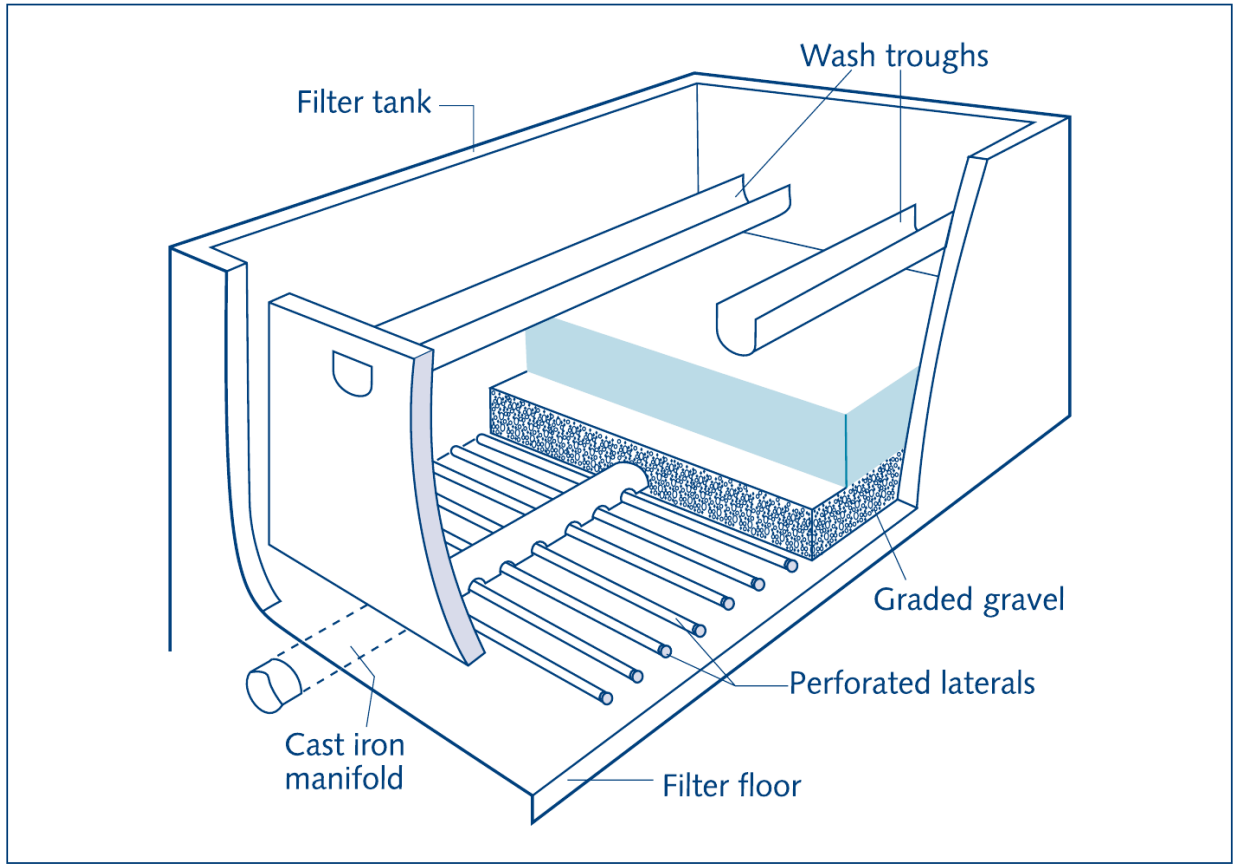
Process

- Straining
- Adsorption



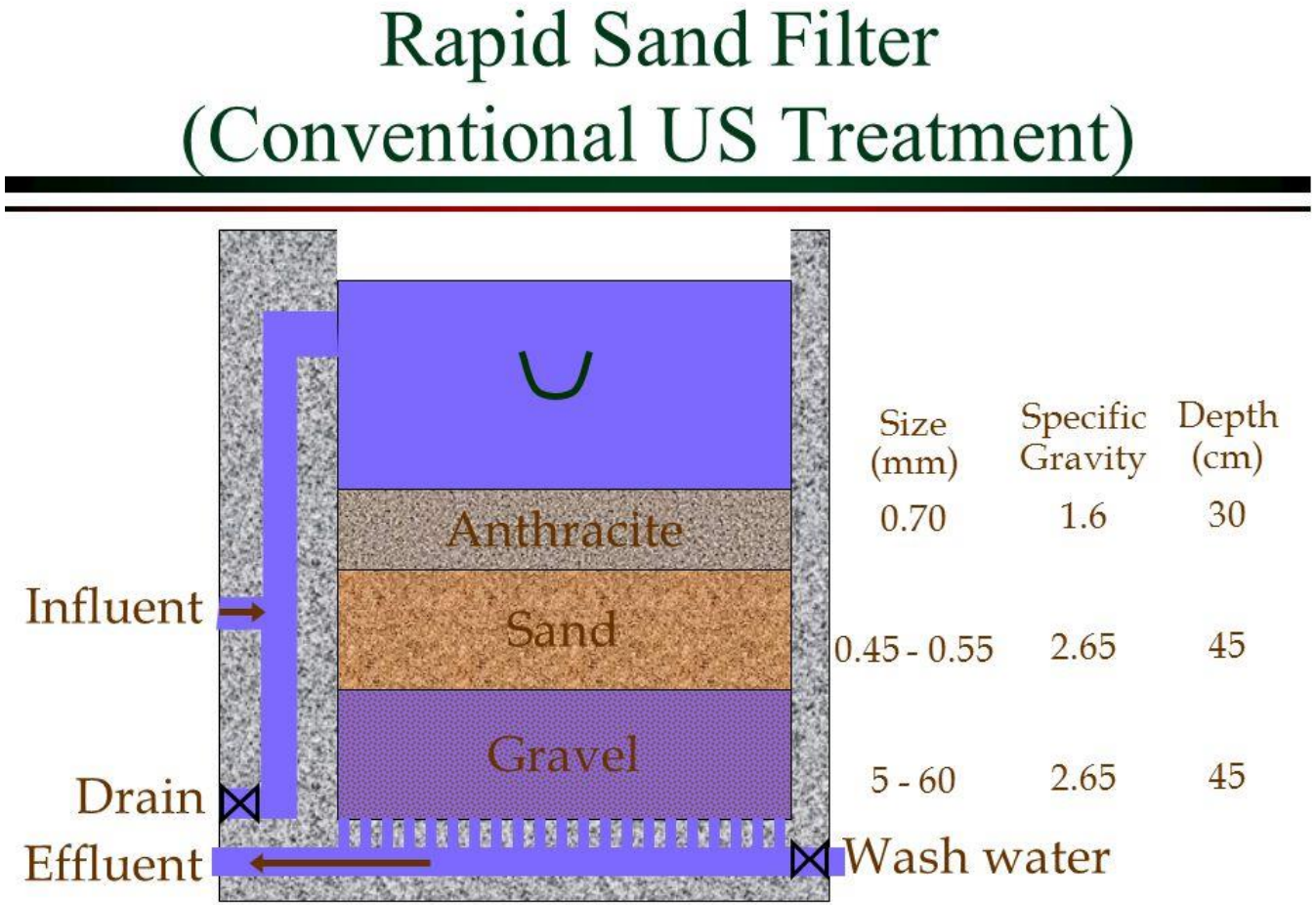
Filter Components

- Filter walls
- Troughs
- Gullet
- Media
- Underdrain
- Piping



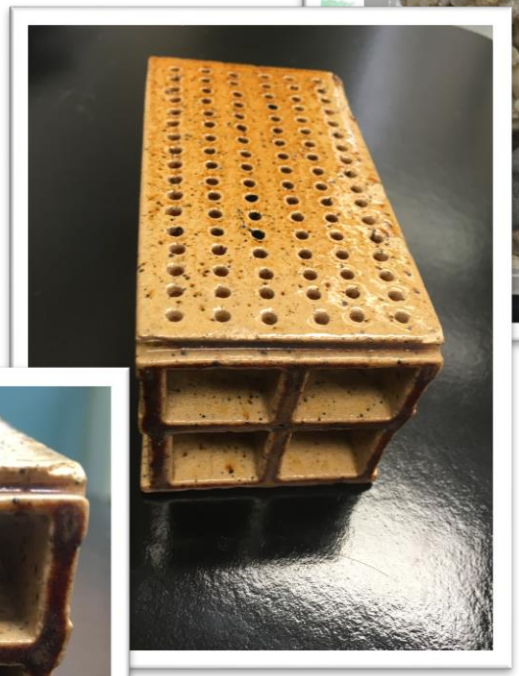
Media

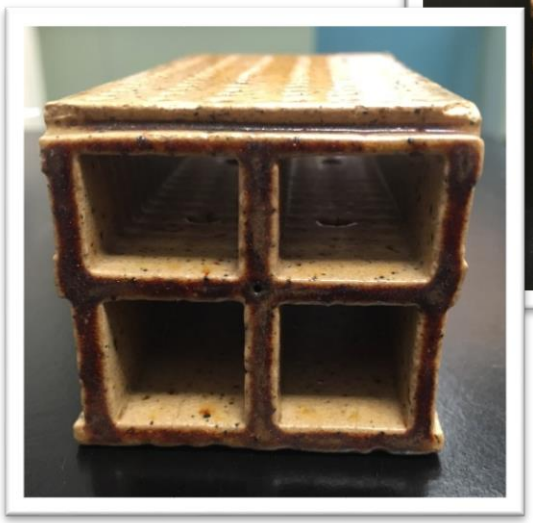
- Sand
- Gravel
- Anthracite



Miami WTP's Media

- Comprised of 7 sections of media:
  - 0.45-0.55mm Filter Sand
  - 0.8-1.2mm Torpedo (Pilot) Sand
  - 1/16"x 1/8" Gravel
  - 1/8" x ¼" Gravel
  - ¼" x ½" Gravel
  - ½" x ¾" Gravel
  - Clay Tiles
- Historically: Anthracite





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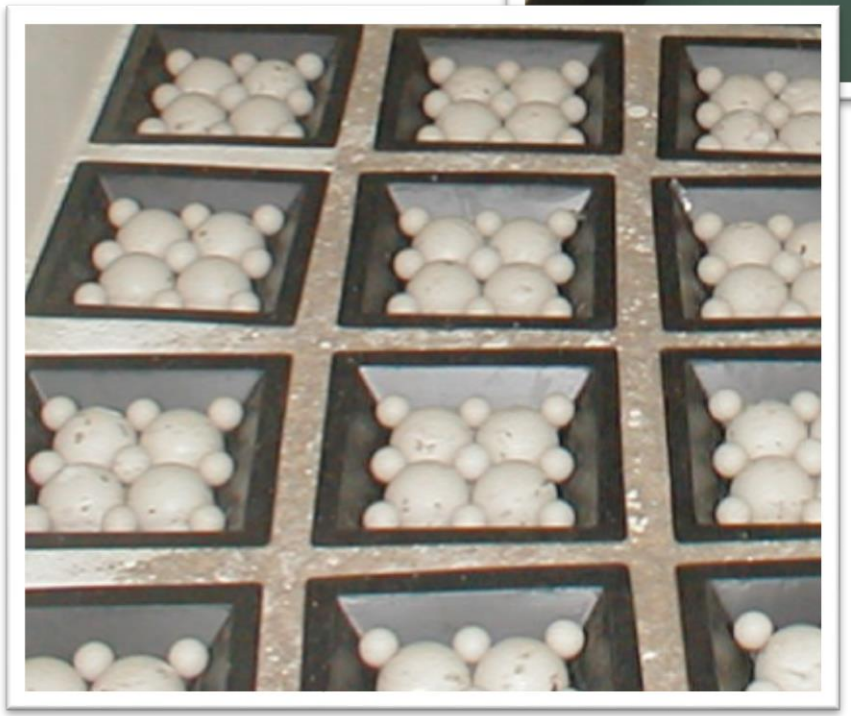
Ottawa WTP's Filter Media

- Comprised of 7 sections of media:
  - 0.45-0.55mm Filter Sand
  - 0.8-1.2mm Torpedo (Pilot) Sand
  - 3/32" x 3/16" Gravel
  - 3/16" x ½" Gravel
  - ½" x ¾" Gravel
  - ¾" x 1-1/2" Gravel
  - Clay Tiles



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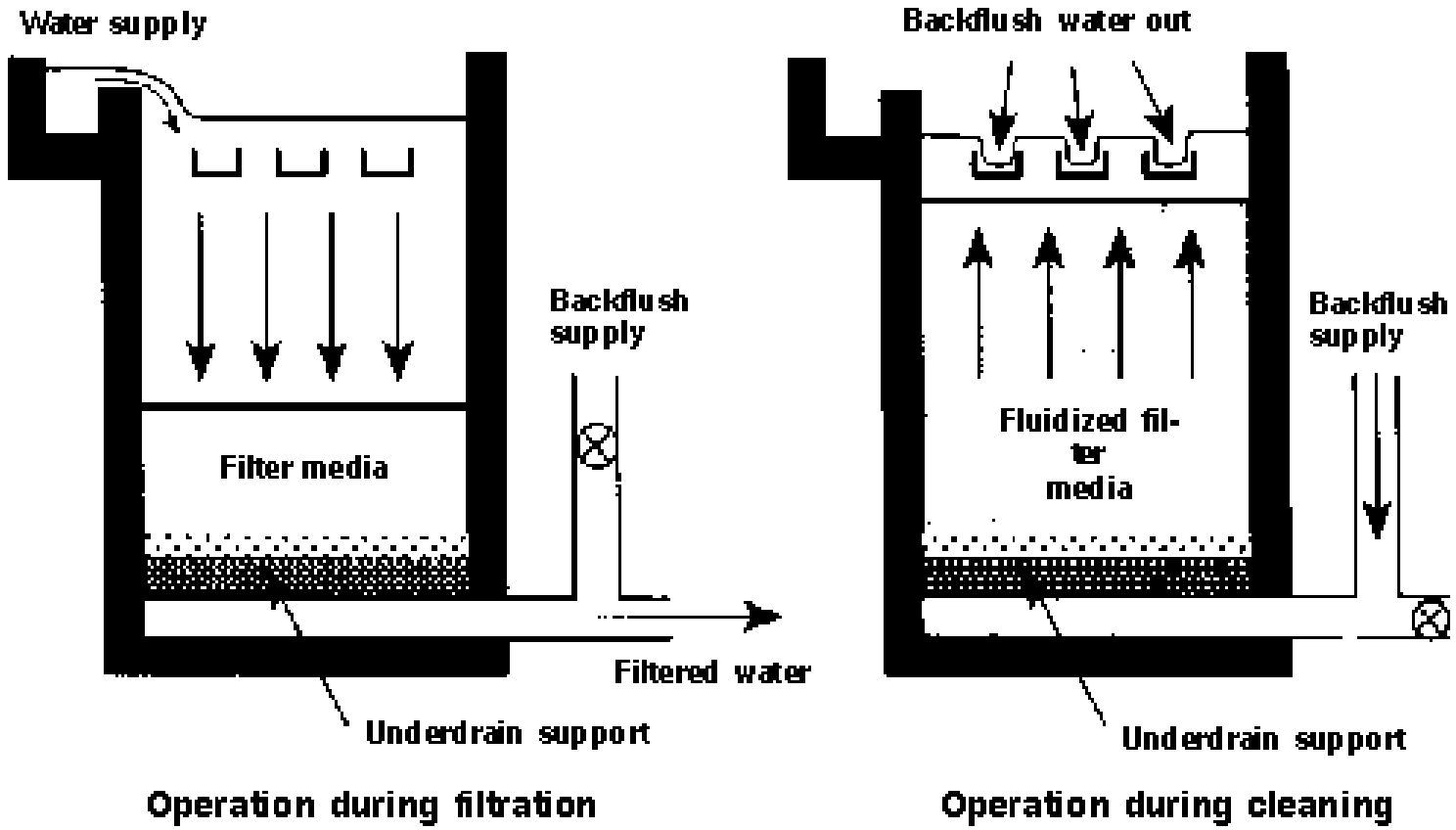
Filter Media Quality

- Gradation
- Specific Gravity
- Effective Size
- Uniformity Coefficient
- Hardness
- Acid Solubility



Cross-section of a rapid sand filter.

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Miami WTP Filter Rebuild

- Clean
- Repair
- Replace

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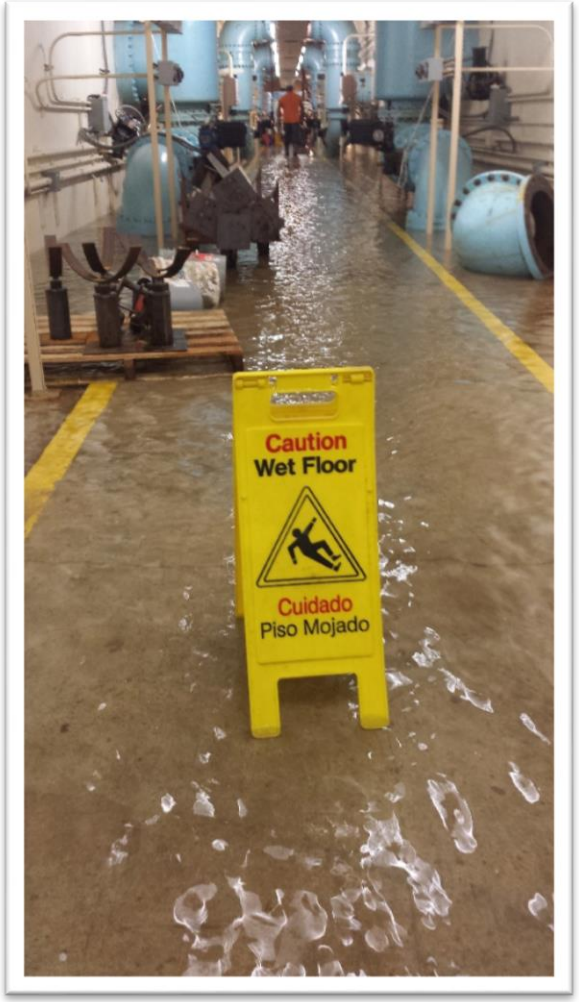

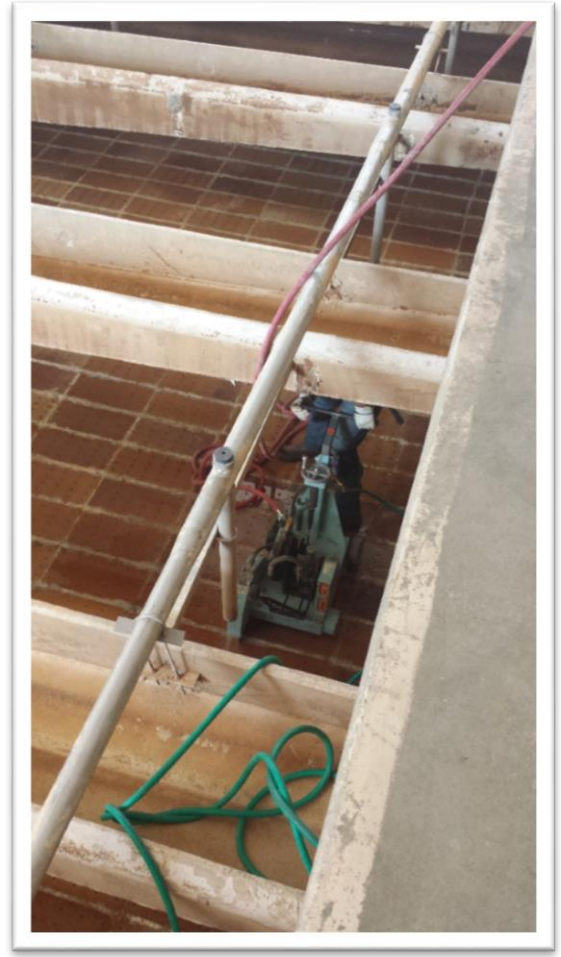

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Filter Maintenance & Upkeep

Miami WTP

- Washed every 40 hours
- Inline Turbidimeters: Hach 1720E
  - Monthly: photocell cleaned, instrument calibrated
  - Quarterly: lens and Aperture plate cleaned
  - Annually: body cleaned, bulb changed

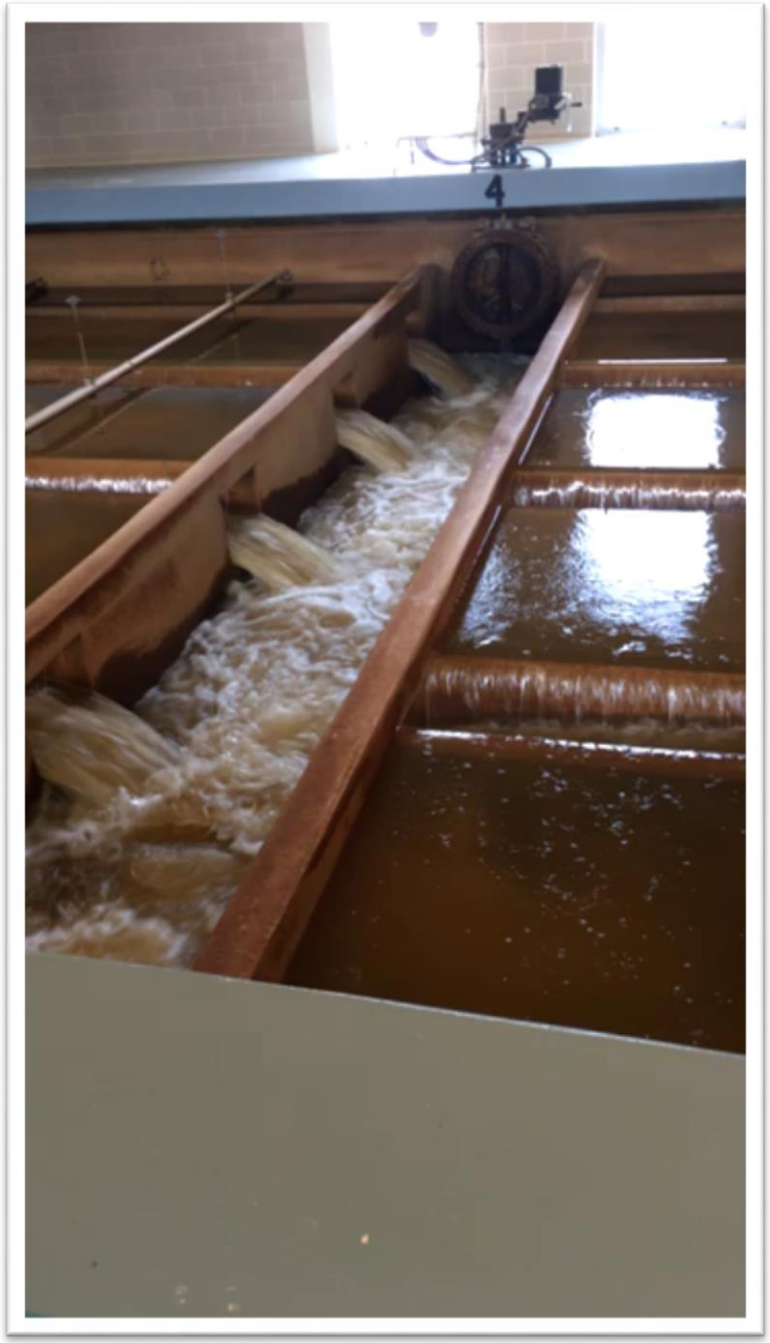
Filter Maintenance & Upkeep

Ottawa WTP

- Washed every 60 hours
- Inline Turbidimeters: Hach TU5300 (Laser)
- Calibrated monthly
- Less upkeep

Filter Wash Purpose

- Clean filter
- Reduce Loss of Head
  - Lime
  - Air Binding
- Prevent Break through
- Reduce Turbidity



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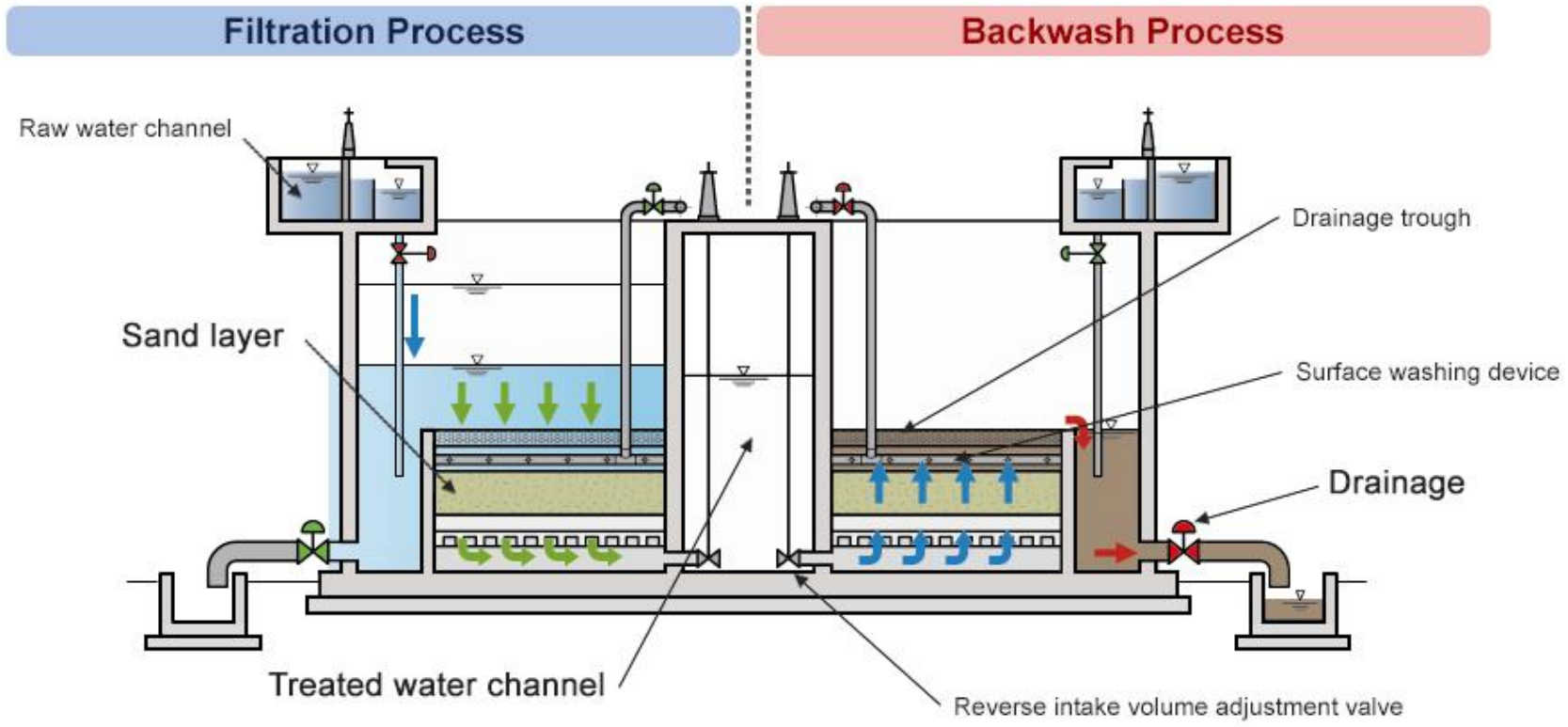
Filter Wash Procedure

- Close Valve
- Open Drain
- Drawdown
- Open wash valve
- Low wash
- Surface sweeps
- High wash
- Close Drain
- Refill



Filter Wash Facts

- Wash water usage
- Wash water tanks
- Water returned to process

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Filter Regulations

- IESWTR requires:
  - Combined Filter Effluent Turbidity 0.3 & 1 NTU
  - Individual Filter Turbidity Standards- 0.5, 1.0, 2.0 NTU
  - Individual Filter Monitoring
  - Filter profiling
  - Filter Assessment
  - Sanitary Surveys

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IESWTR

Filter Profile Method

*The IESWTR requires PWS monitor individual filter effluent turbidity at 15 minutes intervals on a continuous basis using on-line turbidimeter.

If a filter effluent turbidity is >1.0 NTU two consecutive 15 min. intervals at any time (and there is no obvious reason for the abnormal reading) then the PWS must perform a filter profile. **This is a "filter event".**

If a filter effluent turbidity is >0.5 NTU two consecutive 15 min. intervals after the first four hours of service (and there is no obvious reason for the abnormal reading) then the PWS must perform a filter profile. **This is a "filter event".**

The filter profile must be completed within seven days following a **filter event**. A filter profile is done after a backwash cycle. Failure to perform a filter profile within the seven days will result in a monitoring violation and will require public notification.

Equipment

1. 23 clean screw capped Nalgene sample bottles
   Sample bottles are located in the Stock room (and at the water plants).
2. Stopwatch, timer, or watch with a second hand
3. Bench top turbidimeter, Hach 2100AN

Method

1. Label each sample bottle.
2. Locate the filter effluent sample tap in the pipe galley.
3. Flush the sample line of any debris for one minute.
4. Collect samples at one-minute intervals for the first 15 minutes.
5. Next collect samples at five-minute intervals for the next 30 minutes.
6. Finally collect samples at 10-minute intervals for the next 20 minutes.
7. Read the turbidity of each sample on a bench top turbidimeter and record the result.
8. Finally plot the filter effluent turbidity as NTU versus time.

Filter Regulations (cont.)

IESWTR

- Turbidity analyzer fail- grab samples
- Individual filter effluent <0.5 NTU for consecutive measurements during first four hours
- Filter effluent <1 NTU for consecutive measurements during operation
- >0.5 NTU requires “Filter Profiling”

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City of Dayton – Filter Turbidity – Meter failures & Grab Sample Data
PWS # 5703512

➔ **To be used for recording turbidity data every 4 hours when there is a failure in continuous filter turbidity monitoring.**

➔ **Grab sampling can only be performed for up to 5 days. After that, the filter must be removed from service until the turbidity meter is repaired.**

Water Plant _____ **STU #** _____

Filter # _____

Date/Time meter was out of service & back in service_____

TIME	**Filter No. ____**		**Filter No.____**		**Filter No.____**		**Filter No. ____**		**Operator Name**
	MGD	**NTU**	MGD	**NTU**	MGD	**NTU**	MGD	**NTU**	

Filter # _____

Date/Time meter was out of service & back in service_____

TIME	**Filter No. ____**		**Filter No.____**		**Filter No.____**		**Filter No. ____**		**Operator Name**
	MGD	**NTU**	MGD	**NTU**	MGD	**NTU**	MGD	**NTU**	

IESWTR Filter Preventative Measures

- Minimize fluctuations in flow
- Backwashes
- Feeding properly settled water from basins
- Maintain proper pH
- Open valves slowly
- Maintain good equipment

Let’s start the profile!!!

Filter Profile

- Pre-wash Core Samples
- Backwash Filter
  - Sand Expansion (Stick of Cups)
  - Filter Wash Turbidity
- Post-Wash Core Samples
- Sand Depth
- Acid Solubility
- Mechanical Analysis
- Microbiological Profile

Filter Backwashing

- Effective Backwashing depends upon:
  - Backwash rate
  - Filter wash length

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Core Samples

- Examines the layers of media for:
  - Floc Retention Profile
- Tests preformed on samples:
  - Turbidity

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Core Samples

- Floc Retention analyzed using turbidity.
- Floc retention Specifications:
  - Pre-wash: Less than 150 NTU/100 grams below the midpoint depth in a filter.
  - Post-wash: About 30 NTU/100 grams to 60 NTU/100 grams

FLOC RETENTION GUIDELINES FOLLOWING BACKWASH

NTU/100 GRAMS	MEDIA CONDITION	ACTIONS NEEDED
Less than 30	Very clean	Bed is too clean – examine the wash rate and duration- this bed will not ripen quickly.
30 to 60	Clean	A well cleaned and ripened bed – no action needed.
60 to 120	Slightly dirty	Slightly dirty bed – reschedule a backwash retention analysis soon.
Greater than 120	Dirty	Dirty bed – re-evaluate the backwash system and operating procedures.
Greater than 300	Mud ball problems	Mud balls are most likely present – consider filter rehabilitation or rebuilding.
Greater than 2,000	Extreme mud ball problems	Bed must be taken off line and rebuilt to new specifications.

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Core Samples - Before Wash

Miami #10 – East Bay – 1/25/2018	
Floc Retention Before Backwash	
Sand Depth	**NTU/100 Grams**
0-2"	563
2-6"	75
6-12"	117
12-18"	196
18-24"	96

Miami #6 - West Bay – 2/1/2018	
Floc Retention Before Backwash	
Sand Depth	**NTU/100 Grams**
0-2"	2,401
2-6"	78
6-12"	43
12-18"	67
18-24"	51

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Core Samples – After Wash

Miami #10 – East Bay – 1/25/2018	
Floc Retention After Backwash	
Sand Depth	**NTU/100 Grams**
0-2"	89
2-6"	56
6-12"	50
12-18"	78
18-24"	69

Miami #6 – West Bay – 2/1/2018	
Floc Retention After Backwash	
Sand Depth	**NTU/100 Grams**
0-2"	101
2-6"	47
6-12"	30
12-18"	30
18-24"	30

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Sand Expansion (Stick of Cups)

- Examine the media expansion during a filter wash.
- Goal: 30% percent bed expansion
  - < 30%: abundance of floc, shorter run times, breakthrough
  - > 30%: media loss, uses excess amounts of washwater, strips away solids

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Sand Expansion (Stick of Cups)

Miami #3, 2/8/2018			
Cup #	**Height (inches)**	**Grams of Material**	**% Material Rising**
1	3.0	175.67	100.00%
2	6.0	173.50	66.18%
3	9.0	158.31	32.78%
4	12.0	3.28	2.30%
5	15.0	2.41	1.67%
6	18.0	1.86	1.21%
7	21.0	1.43	0.85%
8	24.0	1.17	0.57%
9	27.0	0.94	0.35%
10	30.0	0.69	0.17%
11	33.0	0.18	0.03%
12	36.0	0.00	0.00%
Total		519.45	

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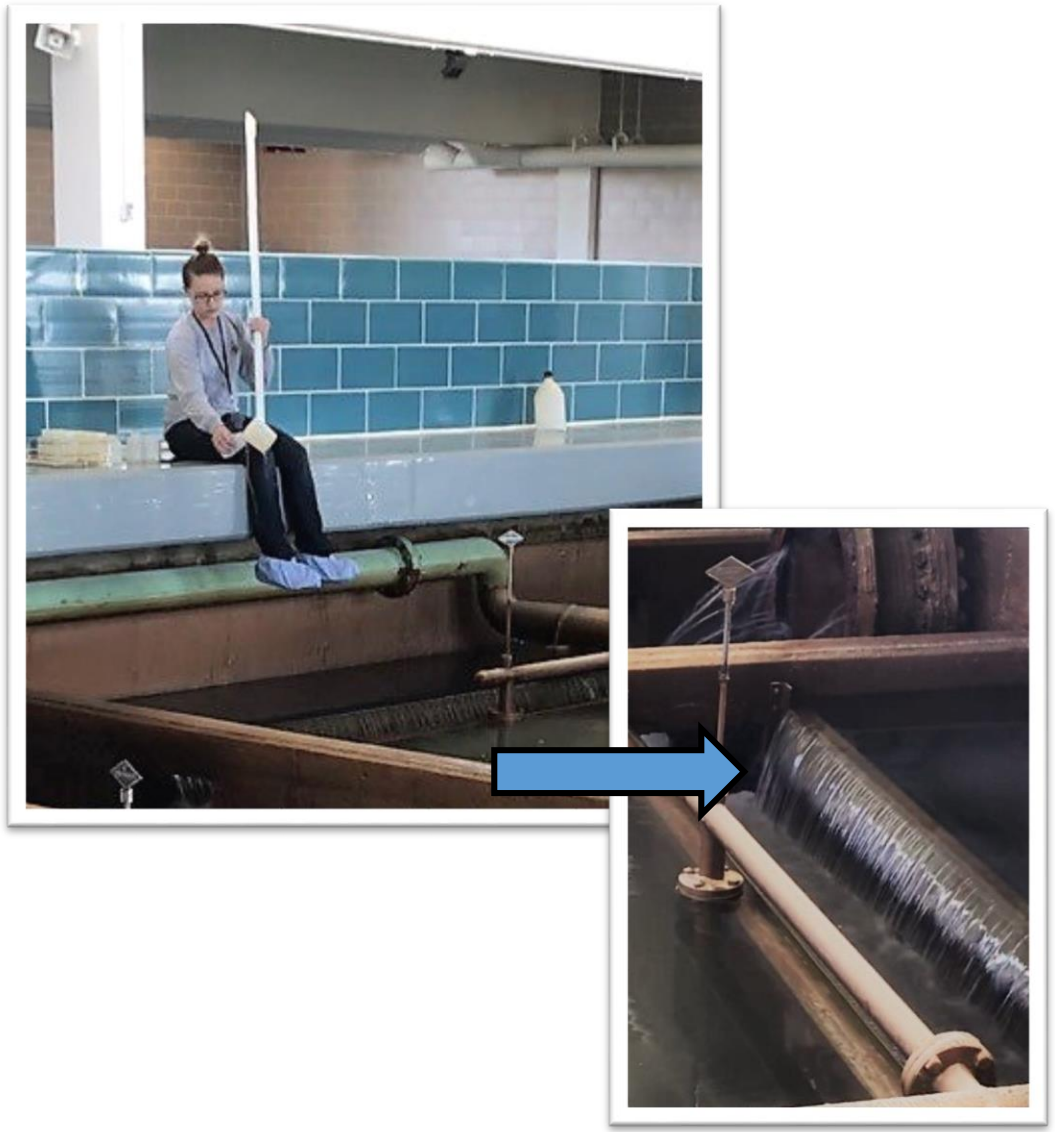
Filter Wash Turbidity

- AWWA recommends that the backwash cycle be stopped once the washwater turbidity falls below 10 NTU



Filter Wash Turbidity

- Turbidity falls under 10 NTU by 4.0 - 4.5 minutes.

Miami #6, 2/1/2018		
Sample #	**Time (Minutes)**	**Turbidity (NTU)**
1	**0.0**	344.00
2	**0.5**	293.00
3	**1.0**	249.00
4	**1.5**	151.00
5	**2.0**	73.30
6	**2.5**	38.40
7	**3.0**	51.50
8	**3.5**	17.70
9	**4.0**	15.80
10	**4.5**	3.55
11	**5.0**	2.46
12	**5.5**	1.05

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Mechanical Analysis

- Analysis the sand size in the different depths of the filter bed.
- Specifications for Miami WTP:
  - Effective Size: 0.45-0.55 mm
  - Uniformity Coefficient: <1.50

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Mechanical Analysis

Miami # 2– 1/18/2018					
Sieve Number	Sieve Size (mm)	East Bay		West Bay	
		Retained	% Passing	Retained	% Passing
10	**2.000**	0.0	100.00	0.0	100.00
12	**1.700**	0.0	100.00	0.0	100.00
14	**1.400**	0.0	100.00	0.0	100.00
16	**1.180**	0.0	100.00	0.0	100.00
18	**1.000**	0.0	100.00	0.0	99.98
20	**0.850**	0.1	99.94	0.1	99.87
25	**0.710**	2.1	97.80	2.3	97.56
30	**0.600**	11.3	86.51	12.8	84.76
35	**0.500**	44.7	41.82	55.5	29.22
40	**0.425**	33.4	8.43	26.9	2.33
45	**0.355**	7.1	1.32	2.1	0.26
50	**0.300**	1.1	0.23	0.2	0.10
Pan		0.2		0.0	
Total		100.0		100.0	

East Bay	
Effective Size (mm)	0.429
Uniformity Coefficient	1.26

West Bay	
Effective Size (mm)	0.446
Uniformity Coefficient	1.24

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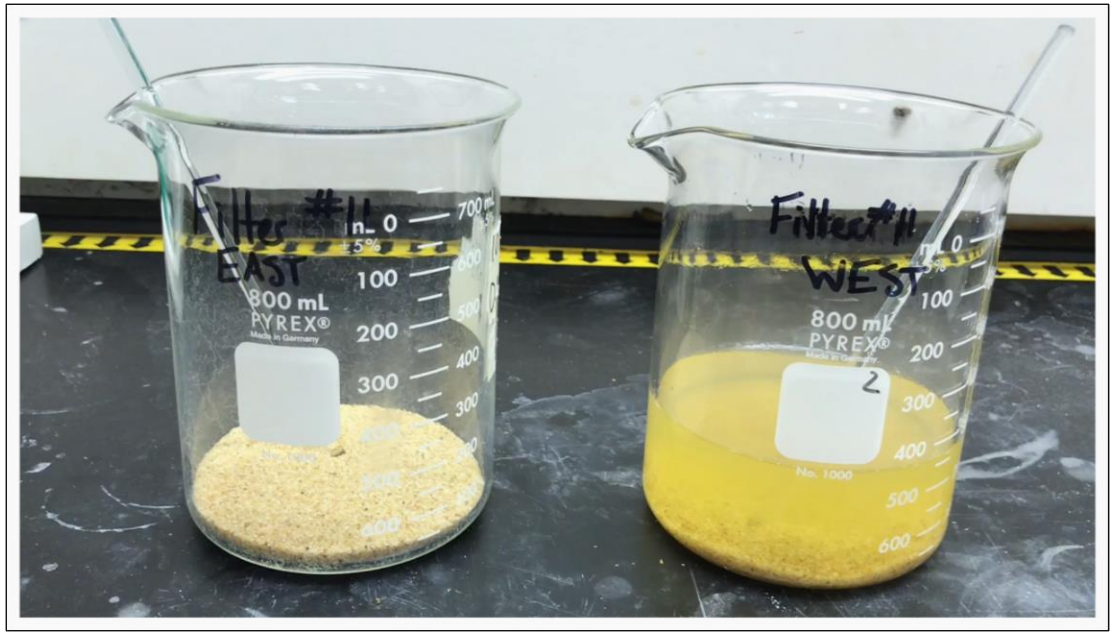
Acid Solubility

- AWWA Specification: Acid solubility of 5% per year or less.
  - Too much deposition: alter the ES and UC of the media rendering it ineffective for removing turbidity.



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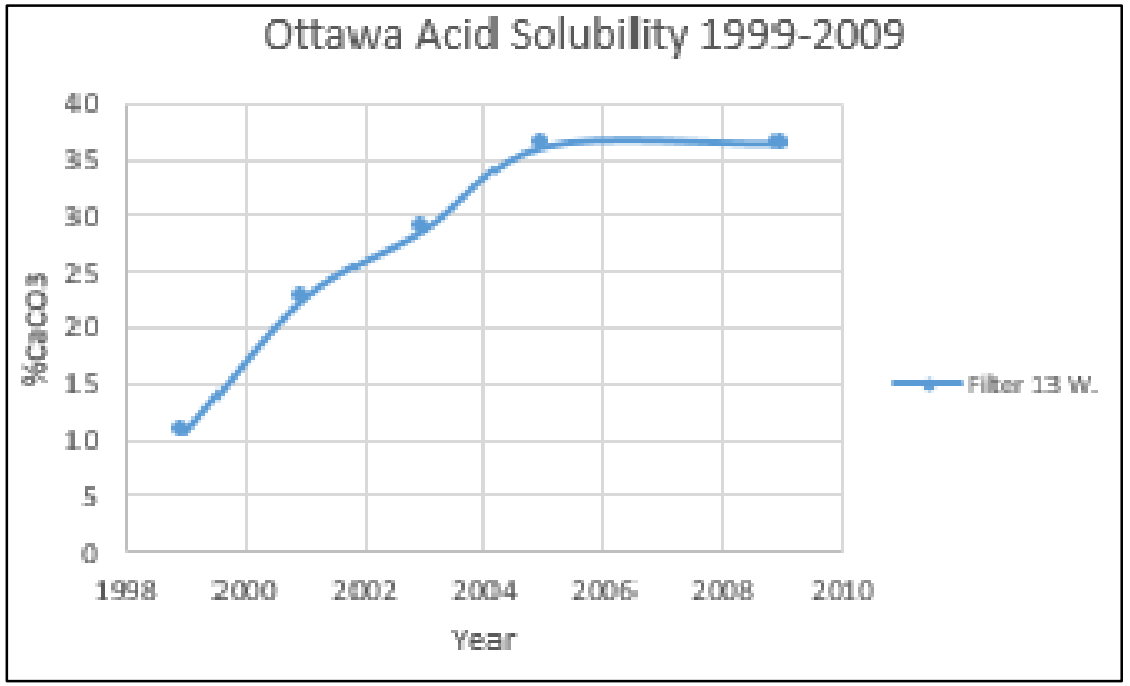
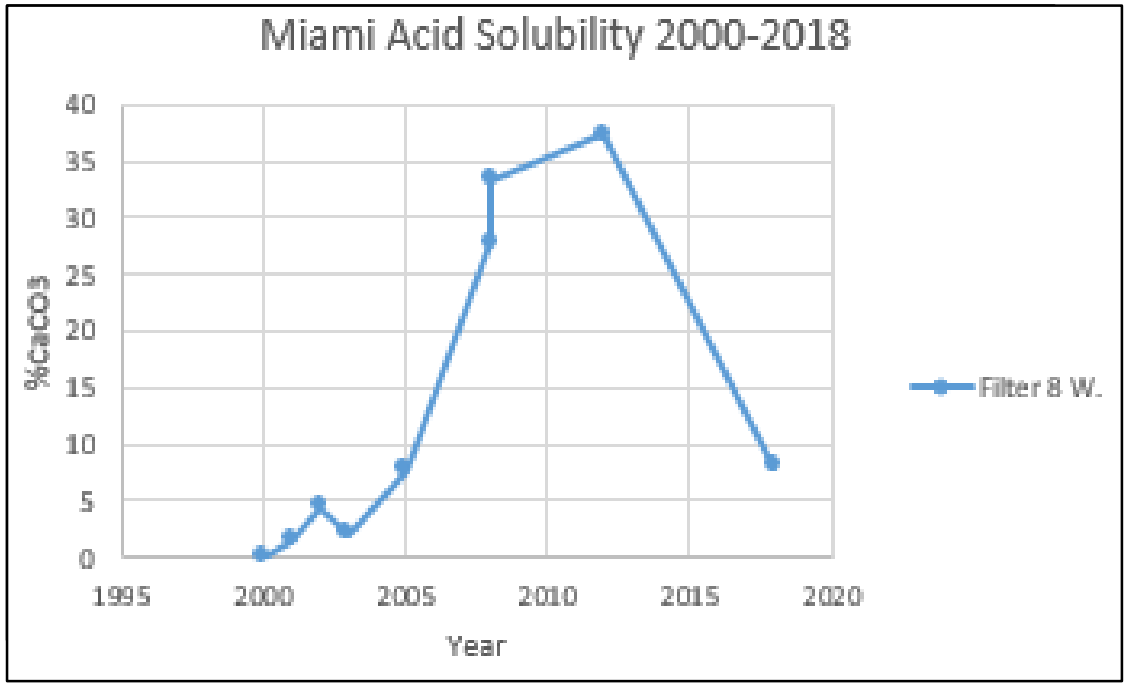
Acid Solubility





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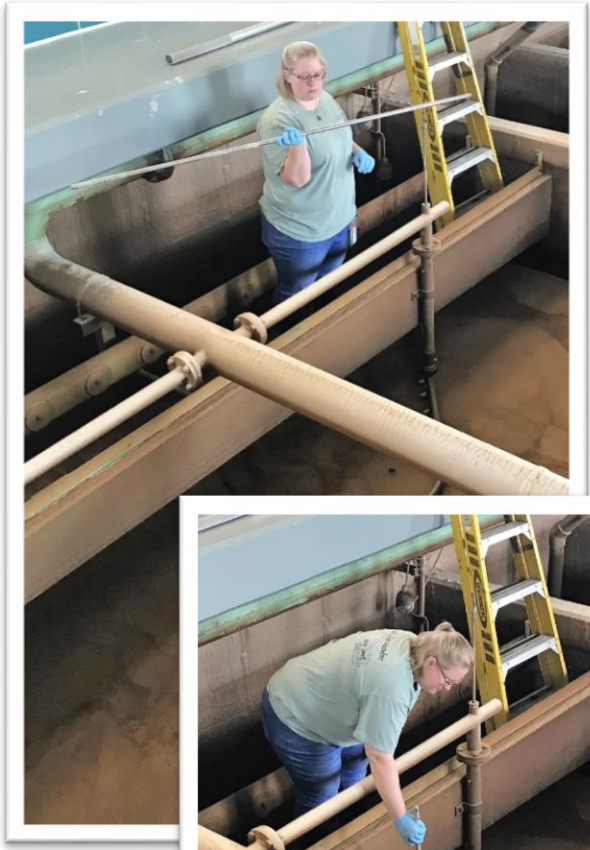
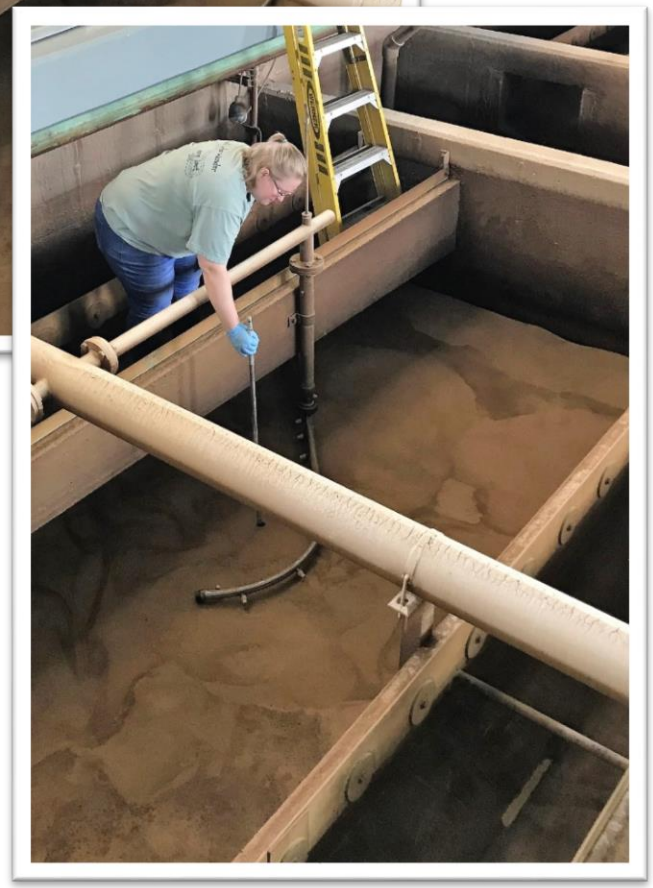
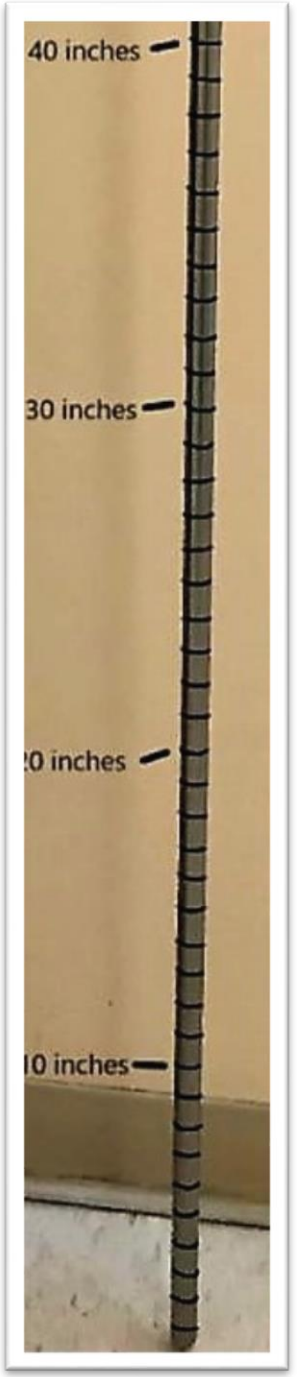
Sand Depth

- Analyze sand depths after the filter wash.
- Original Specifications:
  - Depth of 24” of sand







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Sand Depths

West Bay | Back | East Bay

32	31.5	30.5	30	31		32	30.5	31	31	32
Wash Water Trough						Wash Water Trough				
29.5	32	30	30	30.5		31	31	31	34	31
30	31.5	31	30	30.5		32	32	31	32.5	32
Wash Water Trough						Wash Water Trough				
30	29	30	31	29		31	33	31	31	32
29	29	30	31	31	Gullet	31.5	30	32	31	31
Wash Water Trough						Wash Water Trough				
30.5	30.5	29	30	29.5		30.5	31	29	30	30
30.5	32	28.5	32	30		33	32.5	31	31	32
Wash Water Trough						Wash Water Trough				
33	31.5	30	30.5	30.5		33	32.5	32	33	33
31.5	32	32	31	32		32	32	32	31.5	34
Wash Water Trough						Wash Water Trough				
32	32.5	30.5	30	33		34	33.5	28.5	32	33

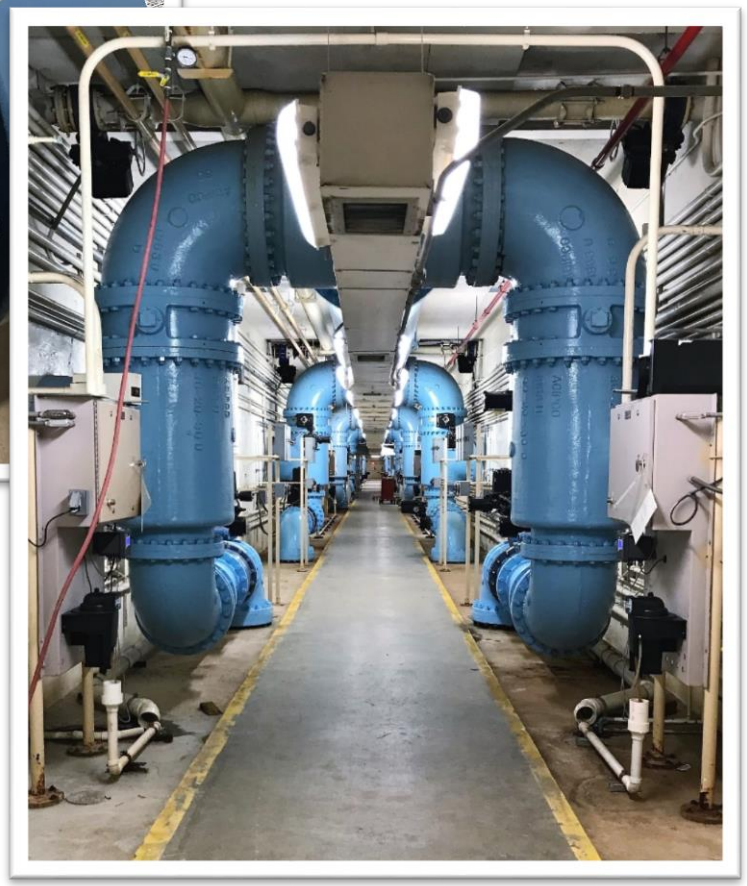
Front

West Bay Sand Depths	
Minimum Sand Depth	28.5 inches
Maximum Sand Depth	34 inches
Average Sand Depth	31.67 inches

East Bay Sand Depths	
Minimum Sand Depth	28.5 inches
Maximum Sand Depth	33 inches
Average Sand Depth	30.67 inches

Microbiological Profile

- Turbidity
- HPC (Heterotrophic Plate Count)
  - Luminultra
  - Membrane Filter Method



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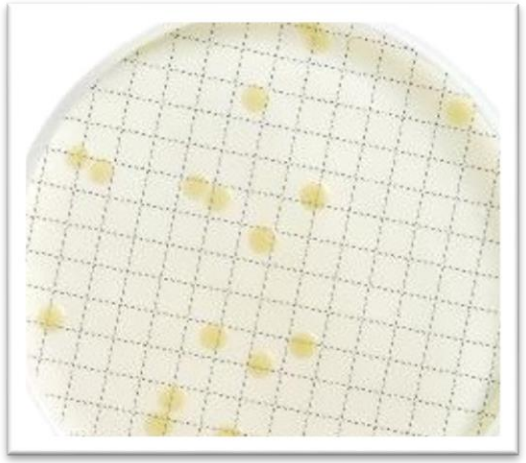
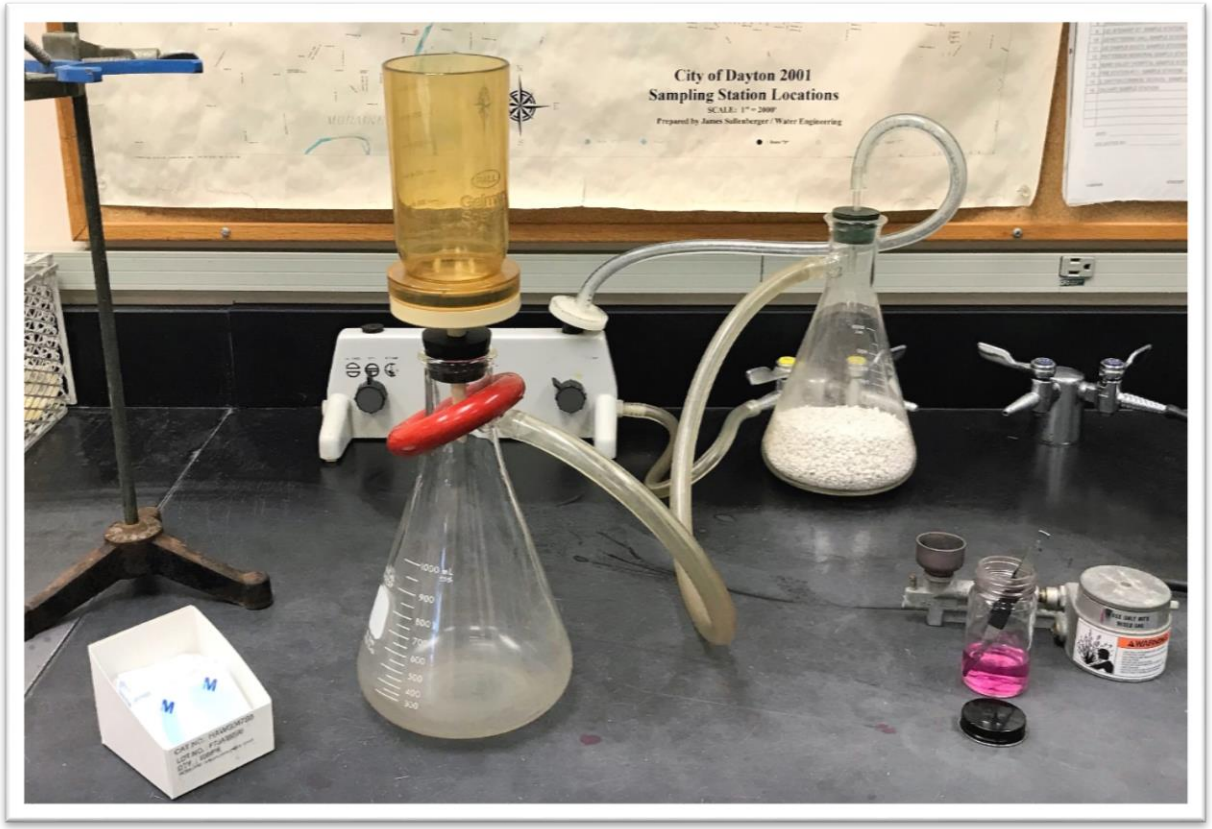
Heterotrophic Plate Count (HPC)

- Luminultra Method
  - Measures ATP
    - Indicator of living microorganisms

Heterotrophic Plate Count (HPC)

- Membrane Filter Method
  - Plated on R2A media
  - Incubated for 48 hours at 35.0 ^{o}C ± 0.5 ^{o}C





QUESTIONS???

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