Enhancing Resiliency of WTPs with Biological Treatment of Drinking Water: Introduction to AWWA MOP M80

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On Behalf of AWWA Biological Treatment Committee

Nov 3, 2025, | 10:30 AM

Biological Drinking Water Treatment is not New

Surface Water Biofiltration

4000 B.C.E
Incidental biofiltration

Early 1800s
Low-rate biofiltration of drinking water

1970s
Rapid-rate biofiltration in Europe

1998
U.S. Stage 1 DBPR

2006
U.S. Stage 2 DBPR

2008 AWWA Committee on Biological Drinking Water Treatment founded

2012
New WRF biofiltration focus area

Biological Treatment of Groundwater

Pre-1980s
Implementation not well documented

1980s
Design to optimize removal of iron, manganese and ammonia

1999
1st full-scale anoxic biotreatment (denitrification)

Biofiltration for Reuse

1969
First DPR facility

2002
1st DPR with biofiltration

2011
1 MGD demonstration facility online in the U.S.

Emerging Contaminants a growing concern

Category	***Compounds***
Flame Retardants	PBDEs, HBCD, TBBPA, Dechlorane Plus, Phosphorus FRs, BFRs
Plasticizers	Phthalates, Bisphenols, Non-phthalates
Cyanotoxins	Microcystins, Cylindrospermopsin, Anatoxin-a, Saxitoxin, Nodularin
PFAS	PFOA, PFOS, PFHxS, PFNA, GenX, PFBS
Pharmaceuticals	Antibiotics, Analgesics, Antidepressants, Hormones
Personal Care	Sunscreen Agents, Fragrances, Antimicrobials

Biological Treatment

Microorganisms found in natural water systems grow on engineered surfaces or media (i.e., form a biofilm) and biologically transform or degrade compounds in the process influent.

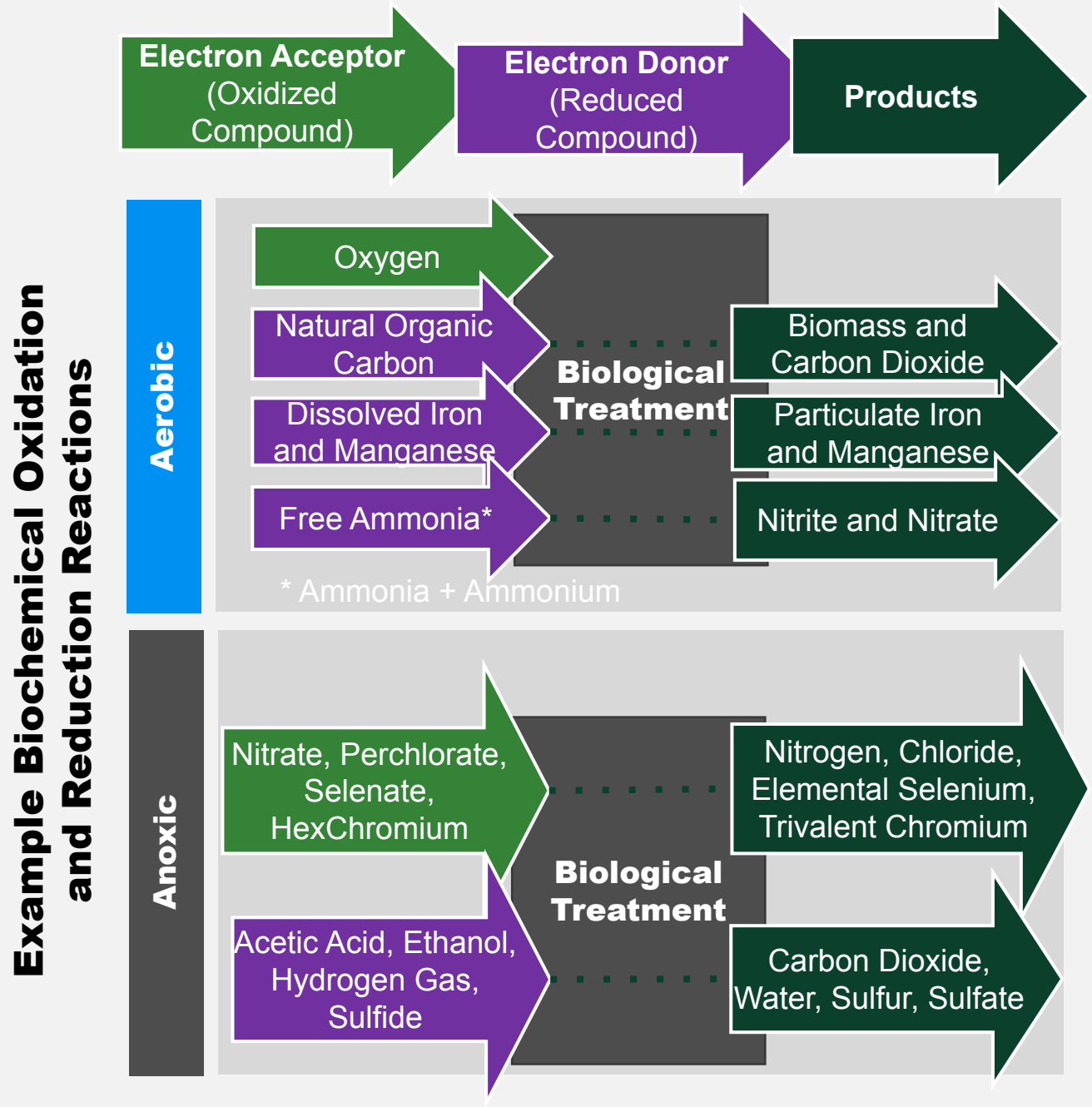
-AWWA M80

Applications	Surface Water*	Groundwater*		Reuse
Conditions	Aerobic	Aerobic	Anoxic	Aerobic

* In some cases, a blend of surface water and groundwater may be treated.

Removal Goals & Mechanisms

- Organic Carbon Compounds
- Inorganic Compounds
- Trace Organic Compounds

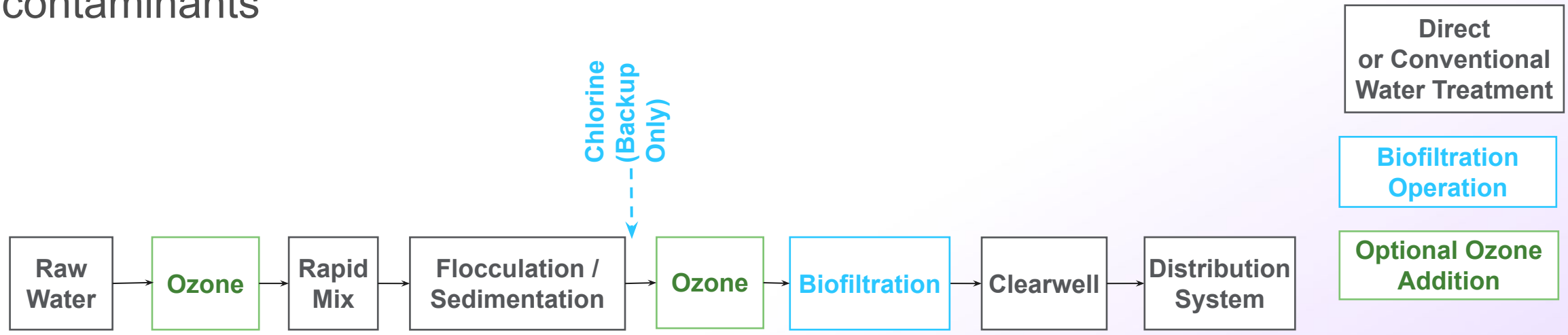


Aerobic Surface Water Biofiltration

Operating conventional/direct gravity filters with low/absent oxidant residuals to encourage biofilm formation

Primary goal: Particle Removal

Additional goals: DOC, inorganic contaminants, and trace organic contaminants



Benefits

Simultaneous contaminant removal:

- Particles (and pathogens)
- Natural organic matter
- DBP precursors
- Taste and odor compounds
- Cyanotoxins
- Pharmaceuticals, personal care products, pesticides, flame retardants, and plasticizers
- Iron, manganese, and ammonia

Increased distribution system biostability

Sustainable & Cost-Effective:

- Low energy/operational costs
- Can be retrofitted into existing filters
- No additional residual waste stream

Optimization

Media Type

Empty Bed Contact Time

Backwash Protocols

Influent Water Quality:
Biodegradable organic matter
Temperature, pH, nutrients
Upstream treatment

Shutdown/Start-Up Procedures

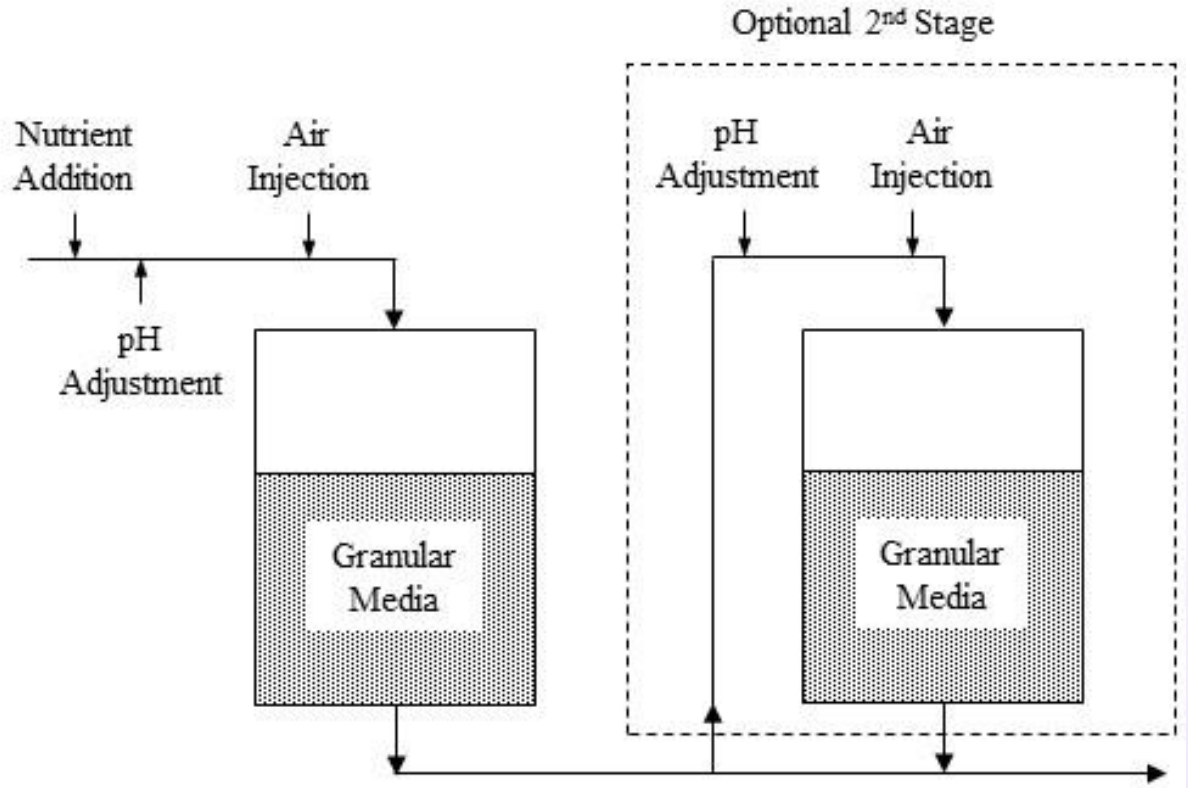
Aerobic Groundwater Biotreatment

Growth of natural microorganisms on media to oxidize dissolved contaminants in multiple configurations:

Open aeration followed by filtration

Air/oxygen injection and pressurized filtration system

Aeration contactor through a coarse bed followed by filtration



Example of Air Injection Followed and Pressurized Filtration

May be referred to as a biofilter if a granular media also designed to remove particles, such as iron, is used

Benefits

Simultaneous (one or two-stage) contaminant removal:

- Ammonia
- Iron
- Manganese
- Arsenic
- Organic Carbon

Sustainable & Cost-Effective:

- Low energy/operational costs
- No concentrated waste stream
- Minimal downstream treatment

Optimization

Aeration

pH Adjustment

Nutrient Addition

MediaType, Size and Configuration

Backwash Protocols and Residuals Handling

Post-Treatment

Anoxic Groundwater Biotreatment

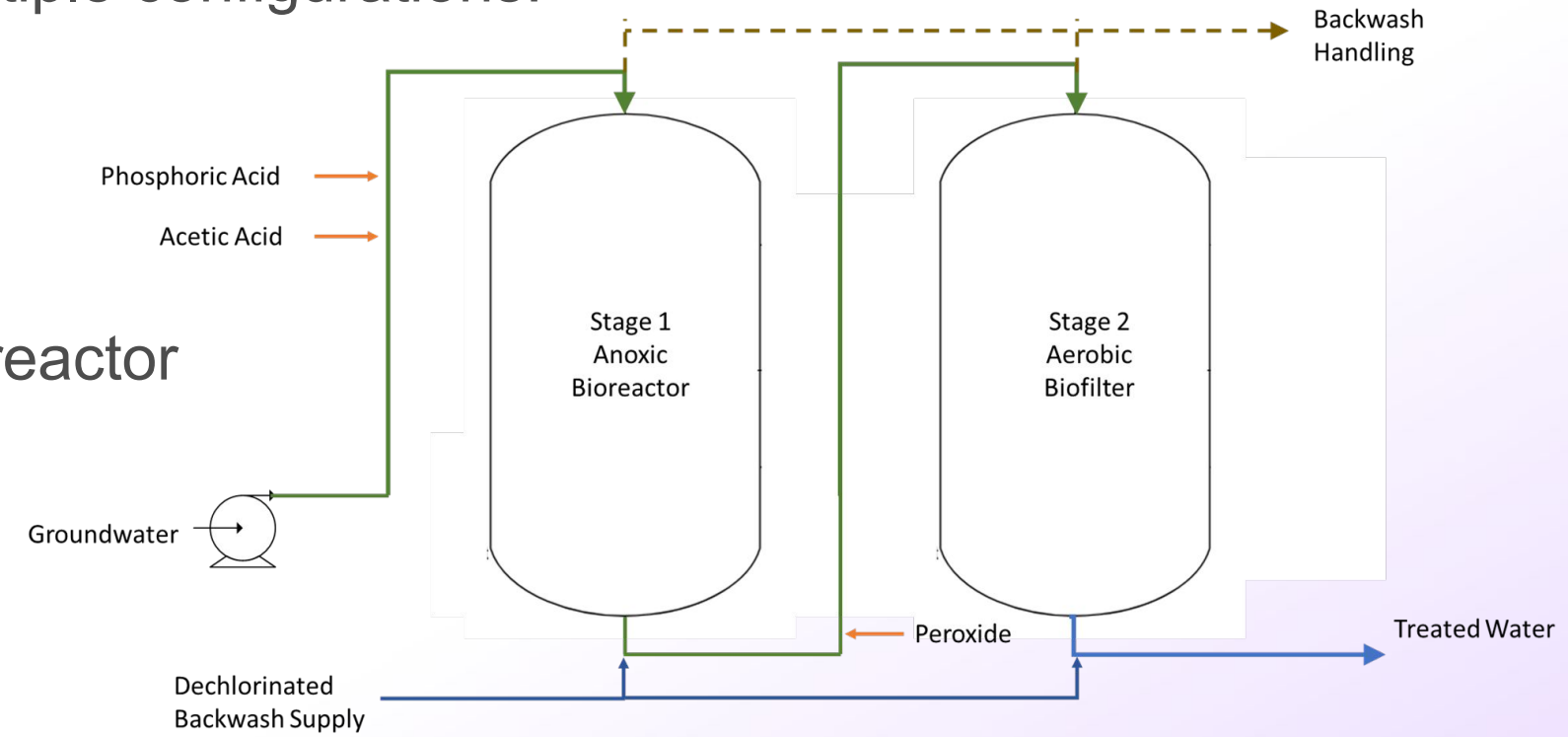
Growth of natural microorganisms on media to remove contaminants in the absence of oxygen, in multiple configurations:

Fixed-bed bioreactor

Fluidized bed bioreactor

Submerged membrane

Continuously stirred-tank reactor



Example Two-Stage Fixed Bed Bioreactor

Benefits

Simultaneous contaminant removal:

- Inorganic contaminants (nitrate, perchlorate, bromate, chromium, and selenium)
- Radiological contaminants
- Volatile Organic Compounds (trichloroethylene and dichloroethylene)

Sustainable & Cost-Effective:

- Low energy/operational costs
- No concentrated waste stream

Optimization

Media Type and Design

Electron Donor (Substrate)

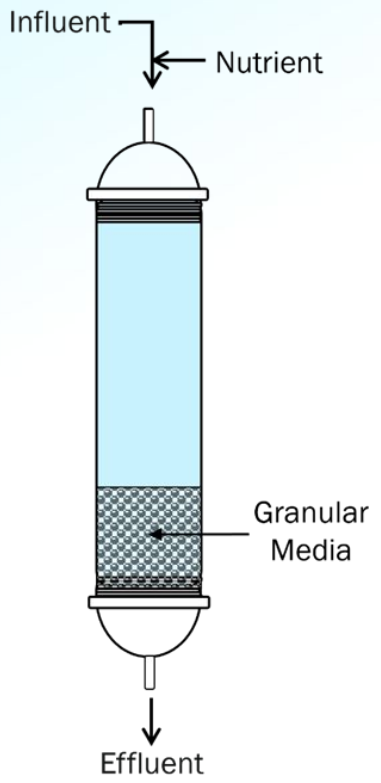
Nutrient Addition

Contact Time

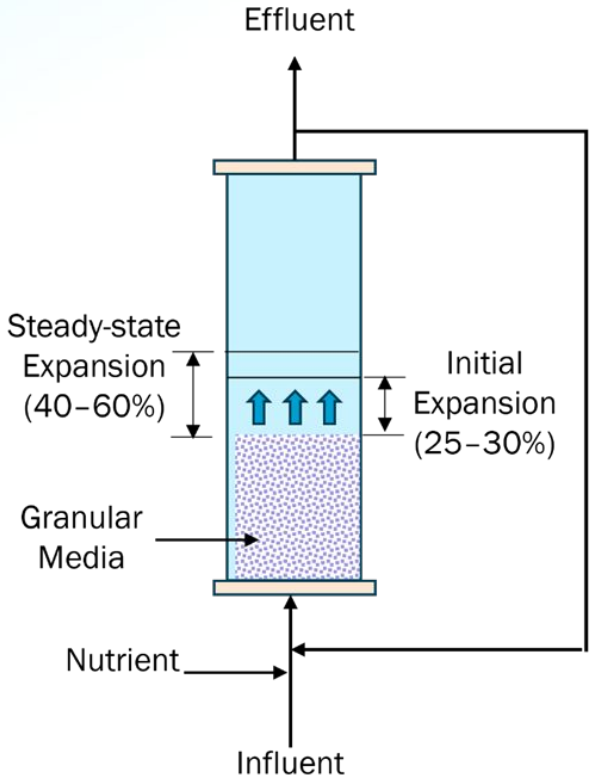
Biomass Control

Post Treatment

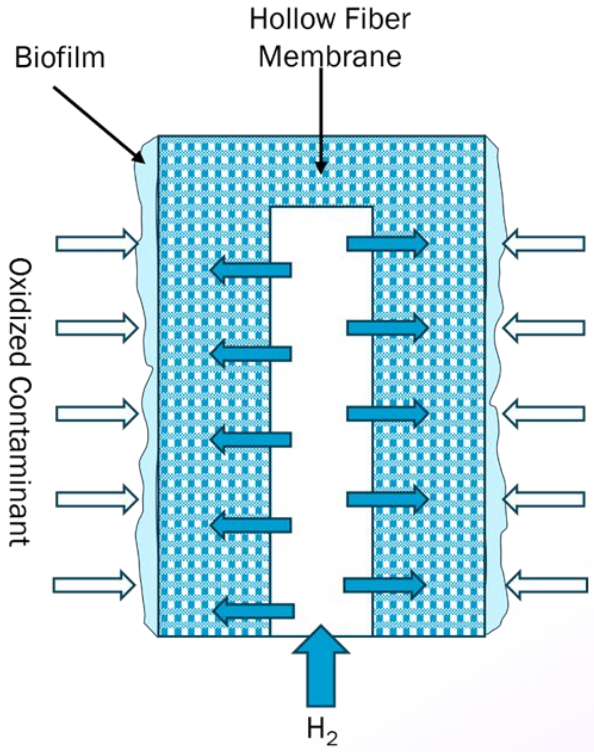
Anoxic groundwater Biotreatment



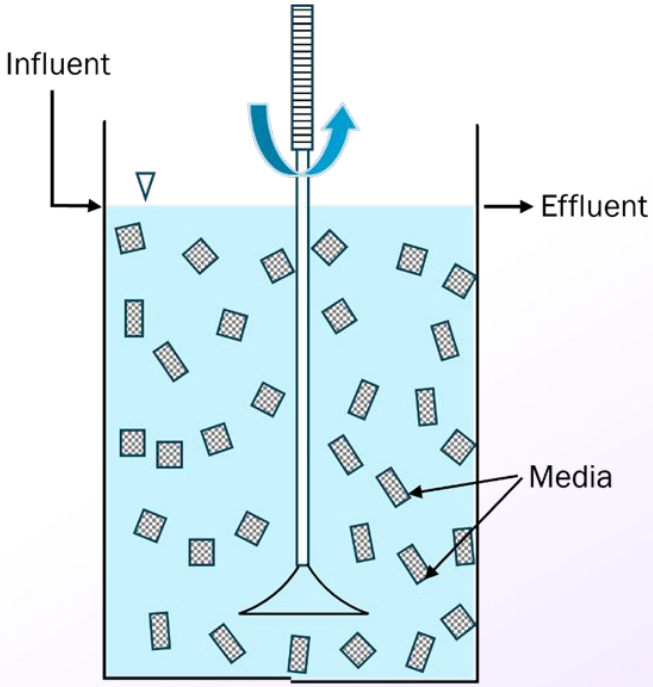
Fixed-Bed Reactor (FXB)



Fluidized Bed Reactor (FBR)

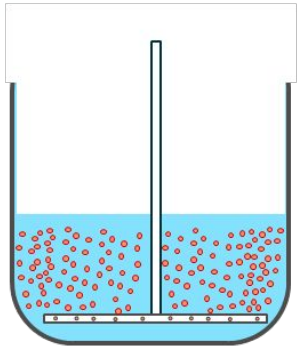


Membrane Biofilm Reactor (MBfR)



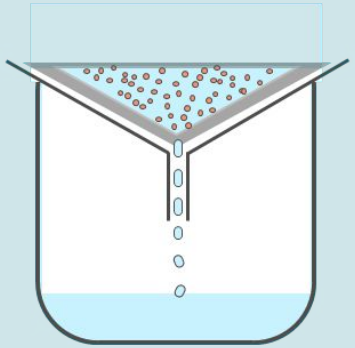
Fixed-film Suspended Media Reactor

Anoxic Biotreatment - Post Treatment

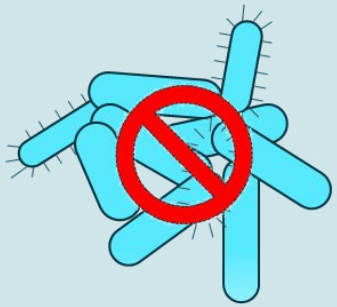


Reoxygenation

Similar to that for surface water treatment processes



Filtration for turbidity removal



Disinfection

Additional Considerations
Recarbonation
pH adjustment

Residual e^- donor removal

Aerobic Biofiltration for Potable Reuse

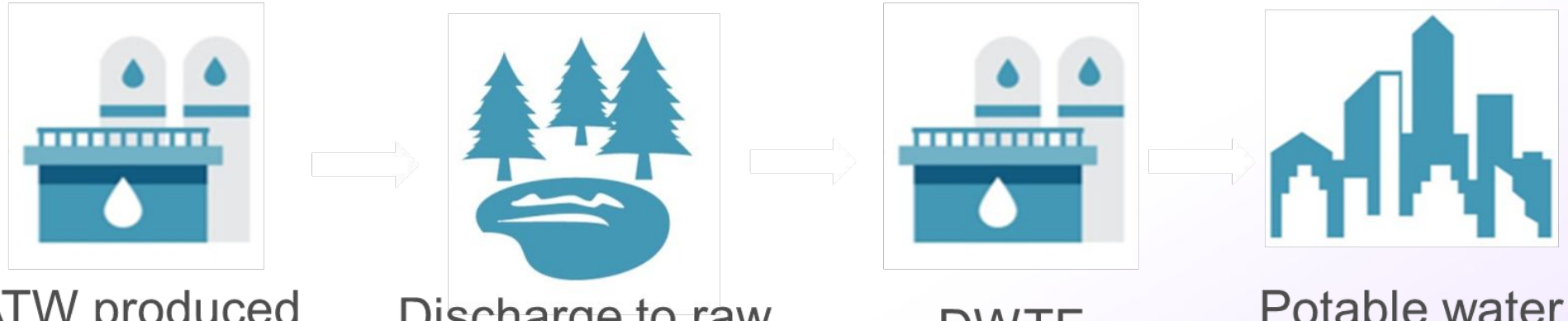
- **Potable reuse** - refers to recycled water that ultimately becomes the drinking water supply. The water is purified sufficiently to meet or exceed federal and state drinking water standards and is safe for human consumption.

Direct Potable Reuse (DPR)

Indirect Potable Reuse (IPR)

Potable Reuse- IPR vs DPR

Indirect Potable Reuse (IPR) - water is blended with other environmental systems such as a river, reservoir, groundwater basin, or aquifer before the water is reused.



ATW produced in an AWTF

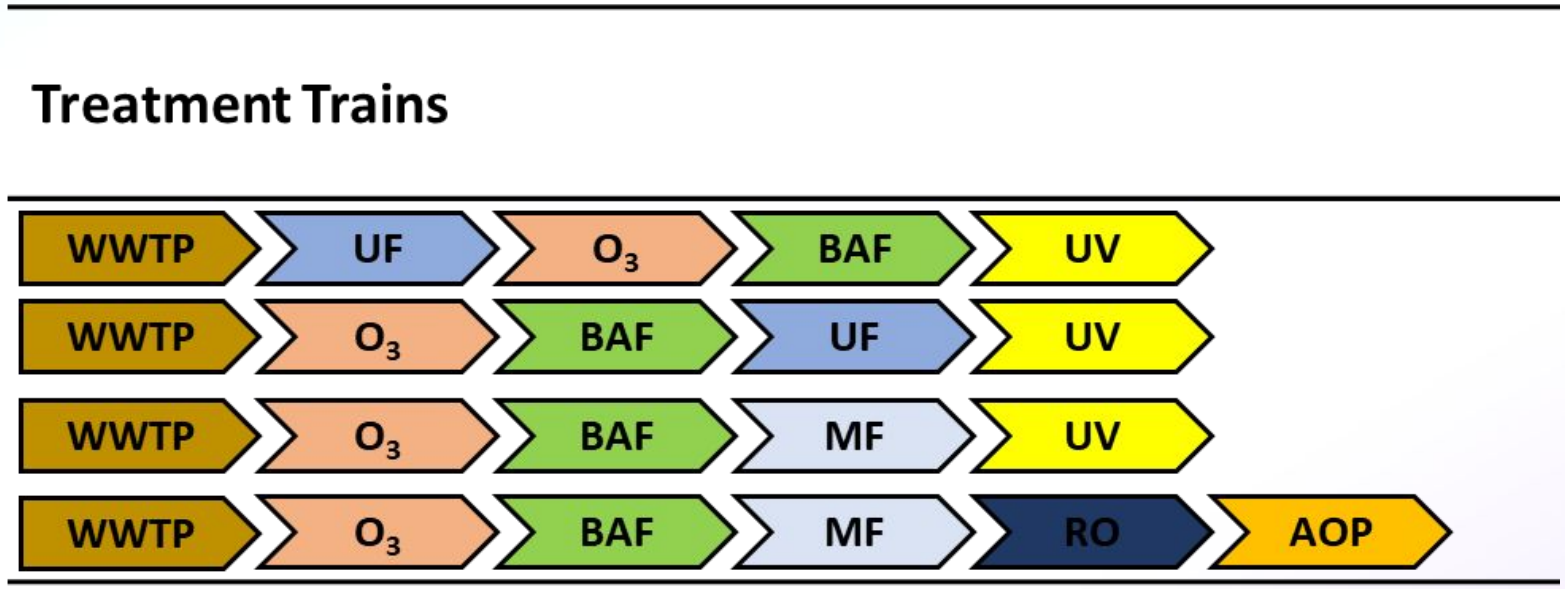
Discharge to raw water supply upstream DWTF

DWTF

Potable water users

Aerobic Biofiltration for Potable Reuse

Operating rapid-rate filters with low/absent oxidant residuals to encourage biofilm formation as part of multibarrier approach



CASE STUDY

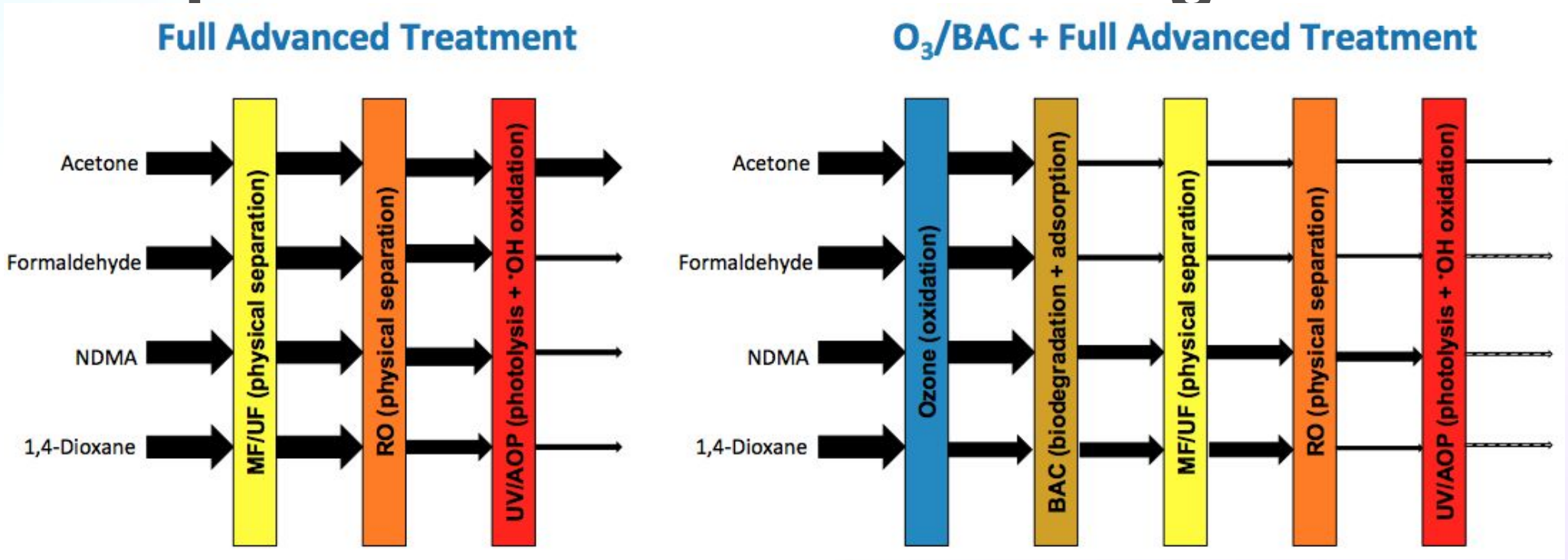
Indirect Potable Reuse

San Diego Pure Water, CA

1 MGD Advanced Treatment Demonstration Facility

- Ozone
- BAC
- MF/UF
- RO
- UVAOP

Incorporating Ozone-BAC into the Pure Water San Diego AWPF Removes Compounds that Persist through RO



Benefits

Simultaneous contaminant removal:

- Dissolved organic carbon
- Trace contaminants (e.g., pharmaceuticals and nitrogenous DBPs)
- Inorganic compounds (e.g., metals, salts)
- Ozonated byproducts

Sustainable & Cost-Effective:

- Critical for inland utilities as part of multibarrier approach (non-RO)
- No concentrated waste stream

Optimization

Upstream Treatment

Pre-Oxidation

Media Type and Design

Empty Bed Contact Time

Backwash Strategies

Post Treatment

Biofiltration monitoring parameters fall into three categories

Water Quality

- ✔ pH
- ✔ Temperature
- ✔ Turbidity
- ✔ DO
- ✔ TOC/DOC
- ✔ UV254
- ✔ Oxidant residual
- ✔ Carboxylic acids
- ✔ Manganese
- ✔ Phosphorus and Nitrogen
- ✔ Target compounds

Additional Monitoring

- ✔ AOC
- ✔ BDOC

Hydraulics

- ✔ Clean-bed and terminal headloss
- ✔ Headloss accumulation rate
- ✔ Filter run time (FRT)
- ✔ Unit filter run volume (UFRV)
- ✔ Filtration rate
- ✔ EBCT
- ✔ Backwash pressure

Biological Monitoring

- ✔ ATP
- ✔ Biofilm formation rate
- ✔ Dissolved oxygen consumption (calculated)
- ✔ Enzyme activity

Additional Monitoring

- ✔ EPS
- ✔ Microbial community characterization

AWWA M80 First Practice Guidance for Document Water Systems

New M80 Manual Examines Biological Water Treatment Applications

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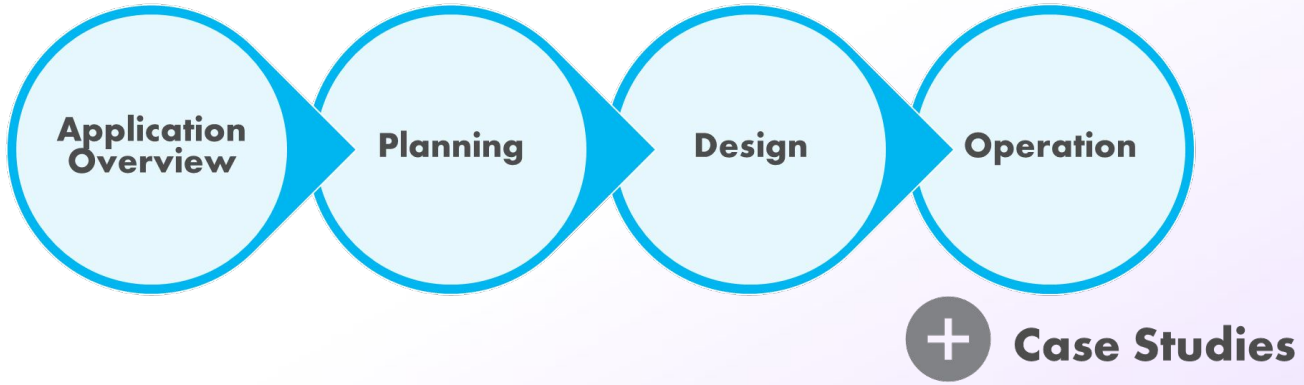
Biological water treatment processes provide robust, cost-effective, and sustainable removal of multiple contaminants, leading to improved resilience in surface water, groundwater, and reuse applications. The use of full-scale biological water treatment applications will continue to increase due to the need for sustainable, cost-effective approaches as well as its ability to simultaneously address a wide range of contaminants in an evolving regulatory landscape.

As a result of the growing interest in biological drinking water treatment, AWWA developed AWWA Manual of Water Supply Practices M80, *Biological Drinking Water Treatment for Surface Water, Groundwater, and Reuse Applications*. AWWA Manual M80 is the first guidance document covering all common biological treatment processes in practice today and contains detailed information on best practices for four areas of biological treatment:

- Surface water
- Groundwater: aerobic and anoxic
- Reuse



Acknowledgements

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