Biological Treatment

for Nitrate Removal in Drinking Water

California Department of Public Health
Drinking Water Program
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Presented by:
Eugene Leung

Outline

- Background
- Treatment acceptance timeline
- Treatment performance requirements
- Demonstration study approach
- Technologies that have completed demonstration or are in the process
- Conditional acceptance letters
- Full scale implementation
- Next steps – Central Valley RWQCB demonstration projects

Nitrate Management Options

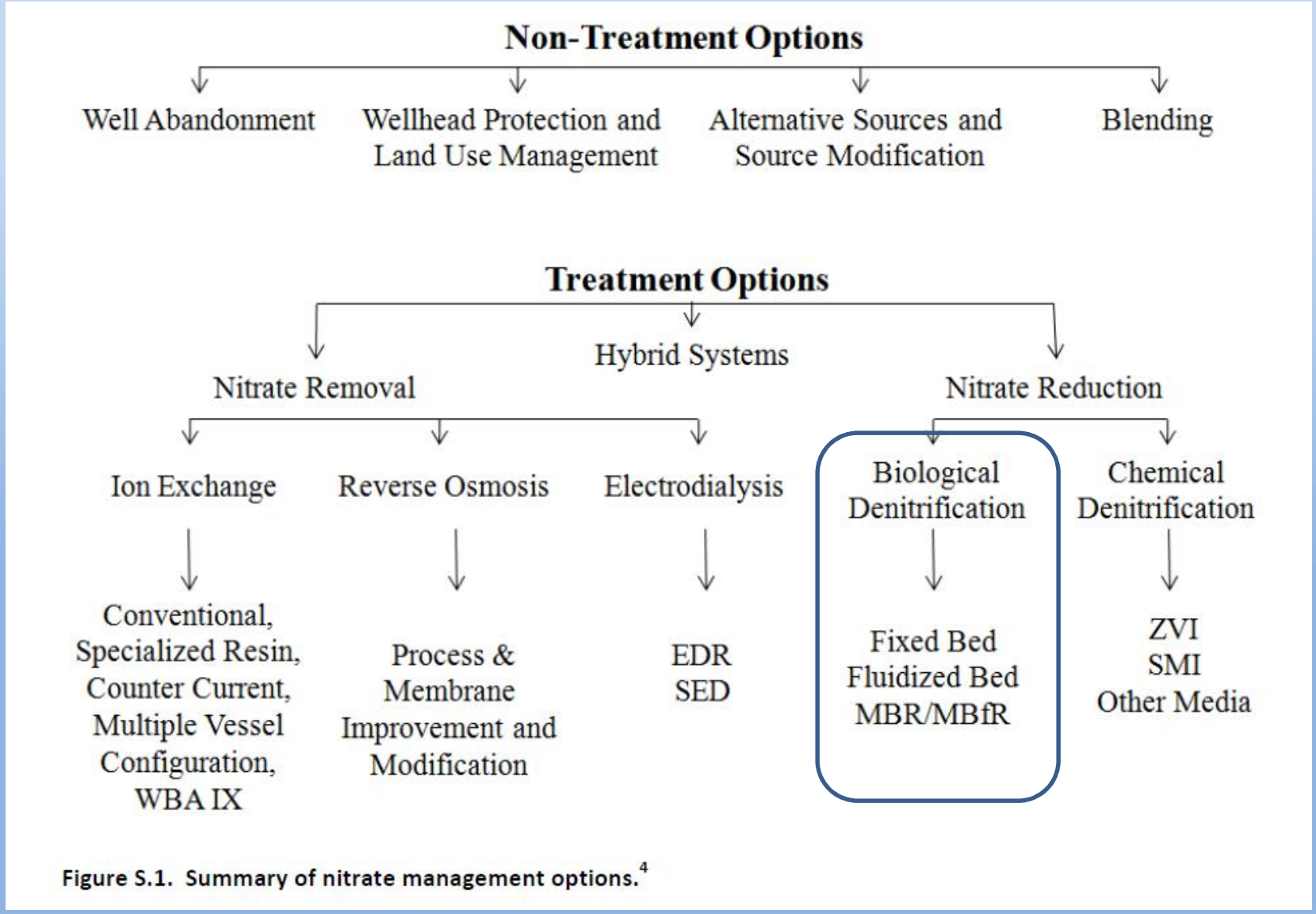


Figure S.1. Summary of nitrate management options.[4]

Source: Drinking Water Treatment for Nitrate, Technical Report 6 by UC Davis & Jacobs Engineering Group

Process Fundamentals

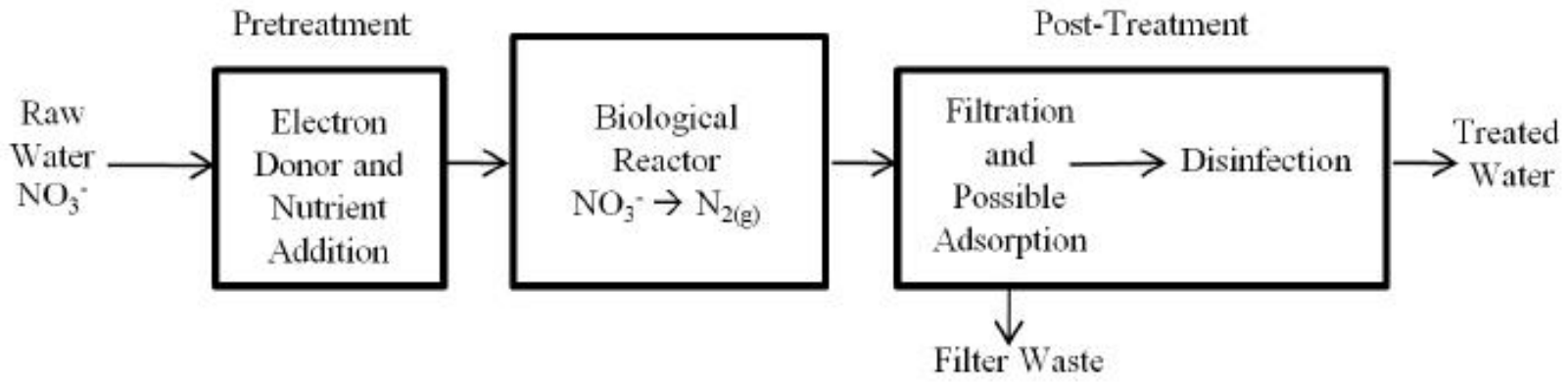


Figure 12. Biological denitrification schematic.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Benefit: There is no concentrated waste stream.

Source: Drinking Water Treatment for Nitrate, Technical Report 6 by UC Davis & Jacobs Engineering Group

Technology Variations

- Bioreactor design
  - Fixed Bed
  - Fluidized Bed
  - Membrane Biofilm Reactor (Rolled-up Membrane)
  - Continuous Stir Tank Reactor (CSTR)
  - Biocatalysts (Microvi)* - bacteria contained inside capsules
  - No one has proposed membrane bioreactor yet (popular for WW treatment)
- Electron donor used (H_2, ethanol, acetic acid)
- Nutrient, site specific (Phosphorous)

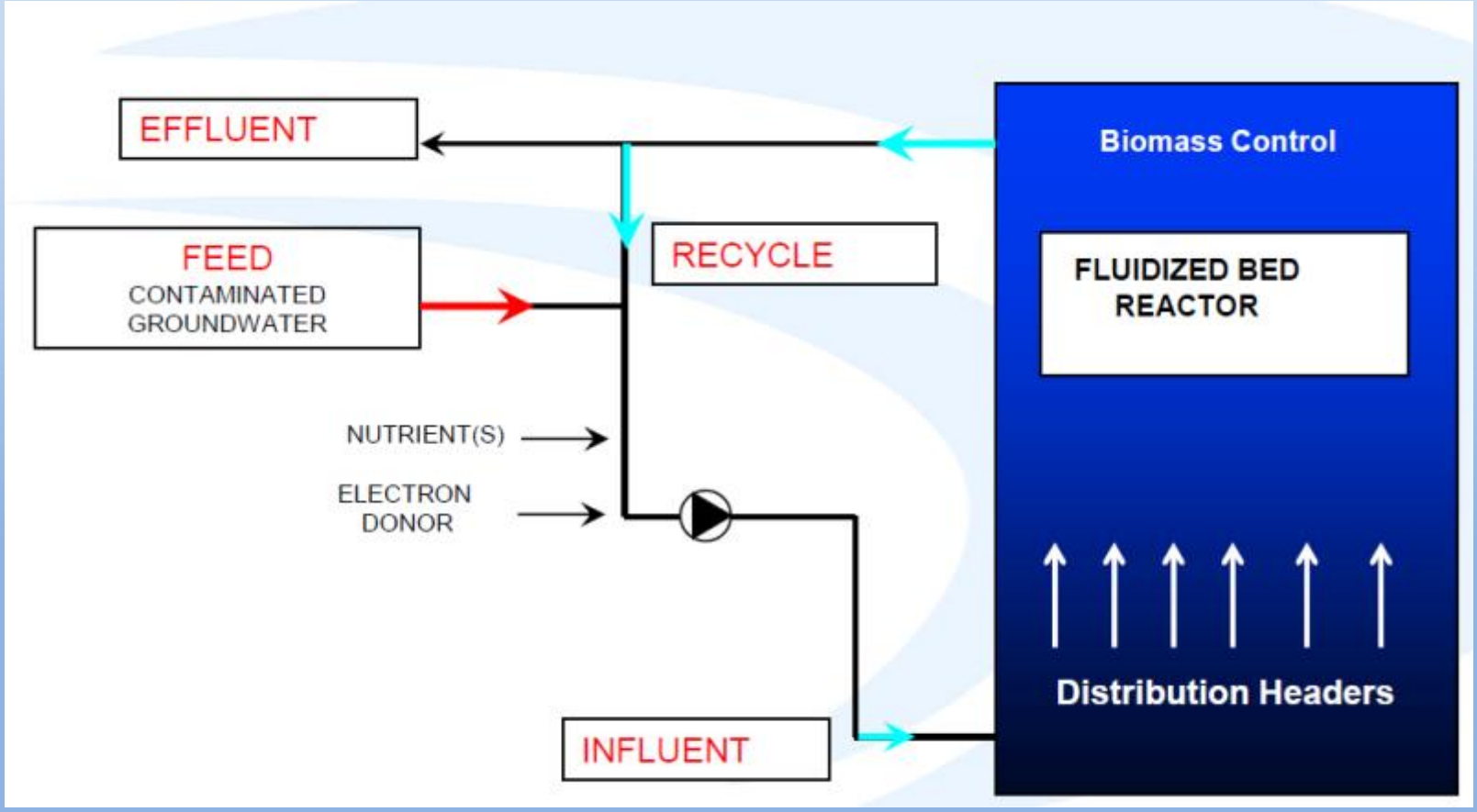
Examples of Bioreactors

Envirogen – Fluidized Bed Design

WQTS and Carollo - Fixed Bed Pilot Systems

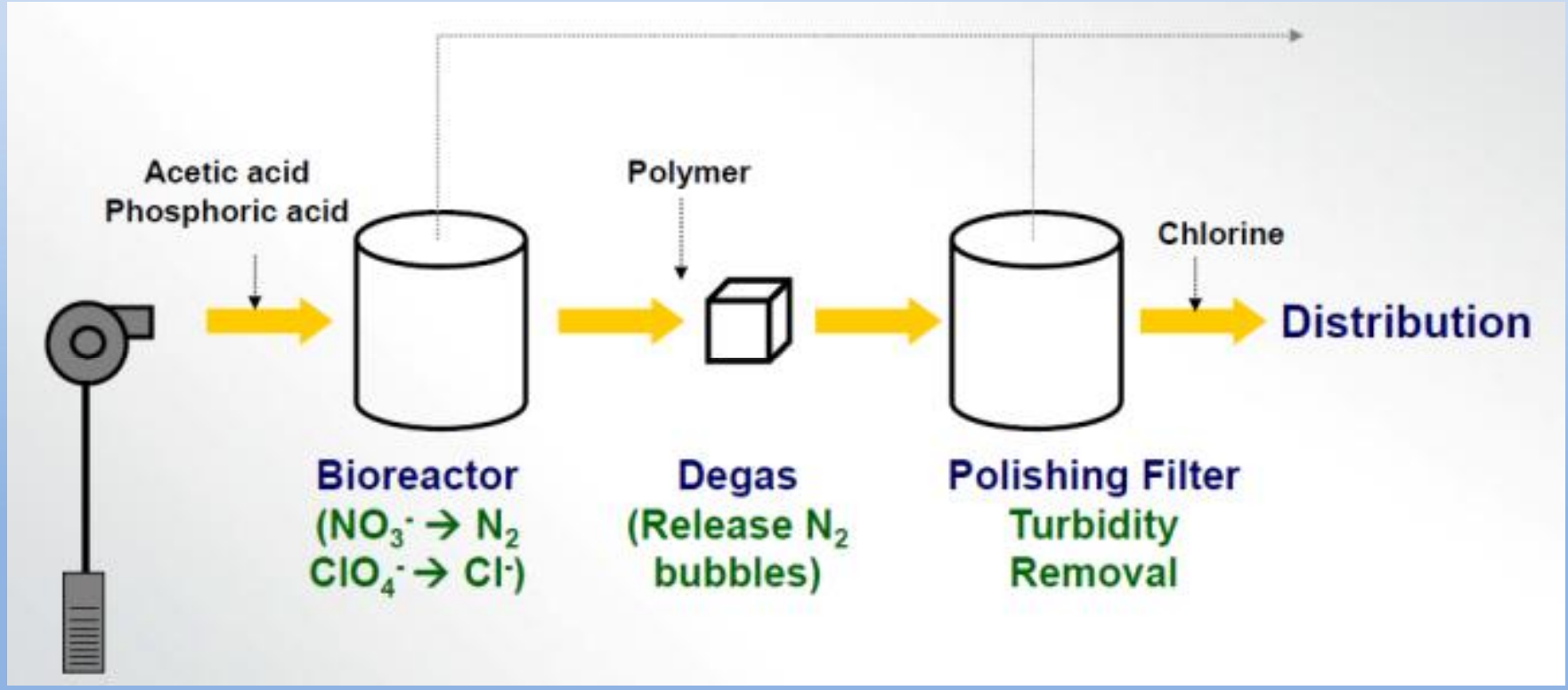
Source: Drinking Water Treatment for Nitrate, Technical Report 6 by UC Davis & Jacobs Engineering Group

Fluidized Bed Process Diagram



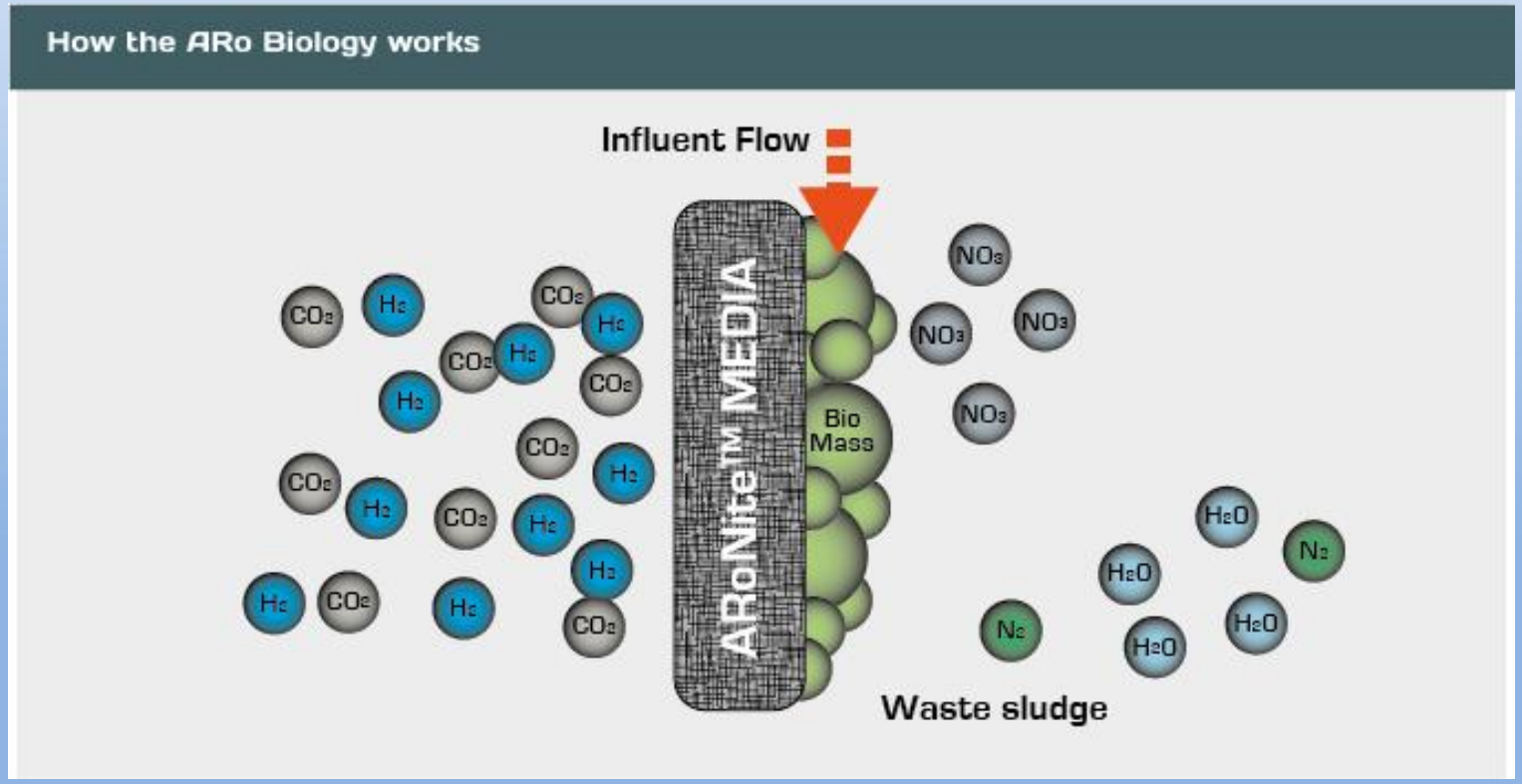
From Envirogen

Fixed Bed Process Diagram



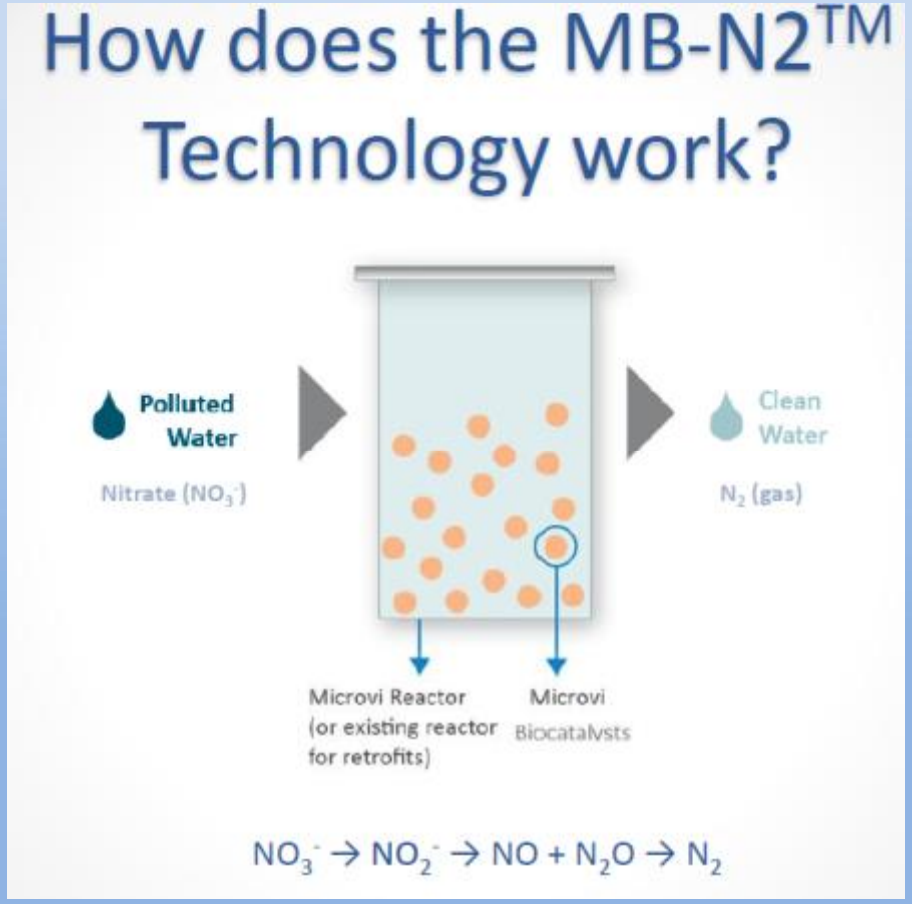
From: Carollo

Membrane Biofilm Reactor



Source: http://www.aptwater.com/our-technologies/specialist-membrane-systems/nitrate-removal/

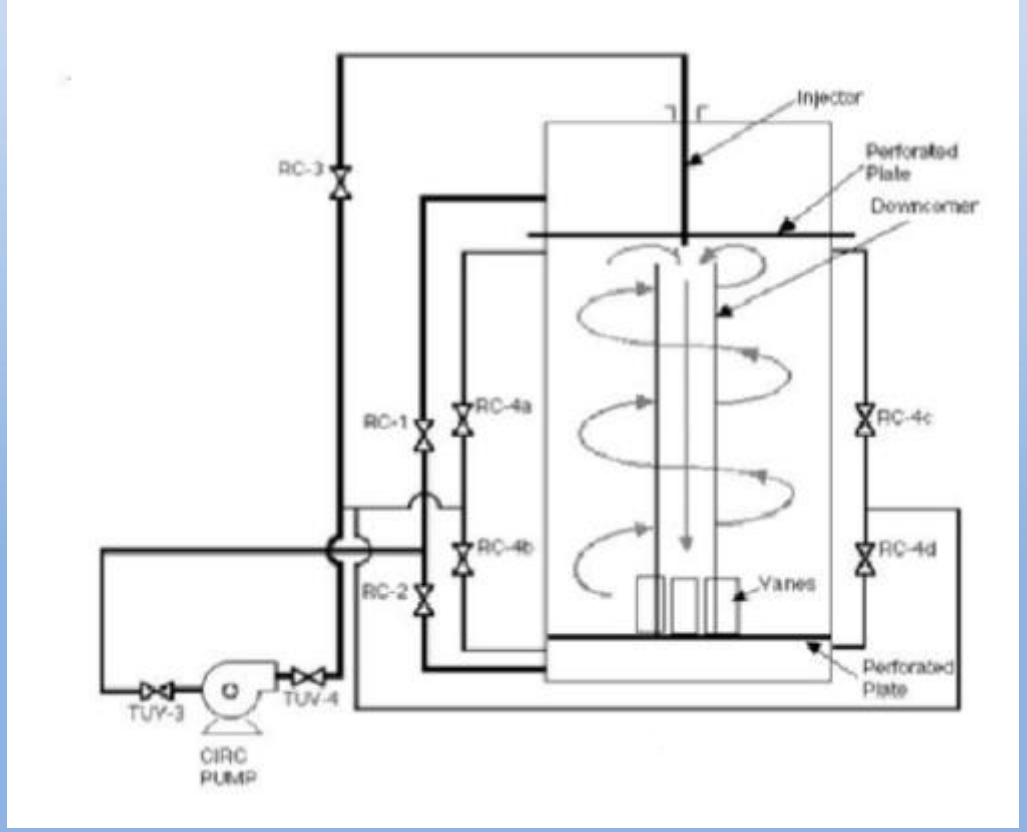
Biocatalyst



More info at: www.microvi.com

Technology currently being tested at Sunny Slope Water System.
Source: http://www.icwt.net/wtc/p12/G-350.pdf

Continuous Stirred Tank Reactor



Technology is patented by MIH Water and currently being tested at West Valley Water District.
Source: http://mihwater.com/wp-content/uploads/2012/03/MIH-Executive-Summary-for-Mark-3-03-2012-120.pdf

Microbes at work…

Indigenous microorganisms is generally used to seed the reactor.

1. Aerobic Respiration (when oxygen is present)
2. Nitrate Reduction
3. Perchlorate Reduction
4. Sulfate Reduction

Current Status

Treatment Technology (Company)	Year Conditional Acceptance Granted / Challenge Testing Completed	Current or Recent Projects in California
Fluidized Bed Reactor (Envirogen)	2002	West Valley Water District 2000 gpm WTP completed (San Bernadino)
Fixed Bed Reactor (Carollo)	2004 and amended in 2011	Western Municipal – Pilot only, no full scale design (Riverside)
Fixed Bed Reactor (WQTS)	2013	City of Glendale (Los Angeles)
Membrane Biofilm Reactor (AroNite – APTWater)	2013	Cucamonga Valley WD (San Bernardino)
CSTR Hall Reactor (MIH Water)	Challenge Testing Recently Completed (To Be Reviewed)	West Valley Water District (San Bernardino)
Biocatalyst (Microvi)	Challenge Testing to start soon	Sunny Slope Water Co. (Los Angeles)

Conditions for Acceptance

1. The system is operated in a manner that minimizes changes in production flow rates (e.g., a plant operated 24 hours a day, 7 days a week, 365 days a year to provide a minimum production of water (base loading)).

2. If variability in flow and perchlorate concentration for extended periods of time cannot be controlled and minimized, then product water should be stored to allow analysis before releasing the water to the distribution system.

3. Site-specific tests are required to determine the impact of seasonal and temporal variations in water quality (temperature, available micro and macro nutrients, etc.) on process performance. For example, it is anticipated the exogenous carbon requirement will vary as a function of source water quality, so the impact(s) of variable nitrate concentrations (in time and magnitude) on finished water quality needs to be evaluated.

4. Source of the microbiological seed must be identified and characterized as not containing human pathogens, except when indigenous biota are selected to inoculate the bed. The use of indigenous microorganisms to "seed" the reactor renders this condition moot.

5. All chemicals used in the system must be NSF standard 60 cert accredited laboratory.

6. It is recommended that all components used in the manufactu vessel that come into direct contact with the source water be t certified by an ANSI accredited laboratory.

7. It is also recommended that development continue on a relia control system that would allow feed-forward control of the a based on measured changes in composition and flow.

8. Treatment following biological perchlorate removal, at a mi the pertinent requirements of the Surface Water Treatmen California Code of Regulations, Div. 4, Chapter 17.

9. On-line monitoring systems for perchlorate and nitrate sh into process design for improving process control. Techi monitoring should be tested and performance verified by Environmental Protection Agency's Environmental Tech program (Battelle Memorial Institute, Columbus, OH; cc Rachel Sell).

10. When appropriate, additional organics removal (e.g., a (UV/H_2O_2) and/or granular activated carbon) can be added a location downstream of the fixed bed as independent unit treatment proces It is recommended the fixed-bed biological reactor be the first unit process in the treatment train.

Update to November 15, 2004 Letter

The Department will take this opportunity to update condition No. 8 of the 2004 letter. The existing condition No. 8 is updated to read as follows, in place of the Surface Water Treatment Rule standards that were previously cited:

8. *Following biological treatment, the filtration, disinfection and other treatment processes will be required to meet the following performance standards:*

   a. *4-log virus inactivation must be achieved by the end of the disinfection treatment process.*
   b. *Treated water must be coliform free. Weekly or monthly samples collected at the end of the disinfection treatment process will be required.*
   c. *Treated water must contain HPC of less than 500 cfu/mL. Weekly or monthly samples collected at the end of the disinfection treatment process will be required.*
   d. *Filtered water effluent turbidity must be less than 0.3 NTU. Continuous monitoring of filter effluent will be required.*
   e. *Corrosivity of the effluent water must be monitored and controlled prior to distribution, if necessary.*
   f. *Distribution system disinfectant by-products samples must be collected based on the Stage 2 Disinfectant / Disinfection By-Products Rule and must comply with the Locational Running Annual Average (LRAA) TTHM and HAA5 MCLs.*

Treatment Performance Requirements

- 4-log virus disinfection
- Coliform free water
- Heterotrophic Plate Count (HPC) < 500 cfu/ml
- Effluent turbidity ≤ 0.3 NTU
- Corrosivity is monitored and controlled
- Disinfection by-products, monitored per DBPR
- Water is aerated to provide dissolved oxygen
- Water quality meeting secondary drinking water standards (aesthetics, taste & odor)
  - Chlorine residual and turbidity monitored continuously
  - Coliform and HPC monitored weekly or monthly
  - pH by daily grab sample

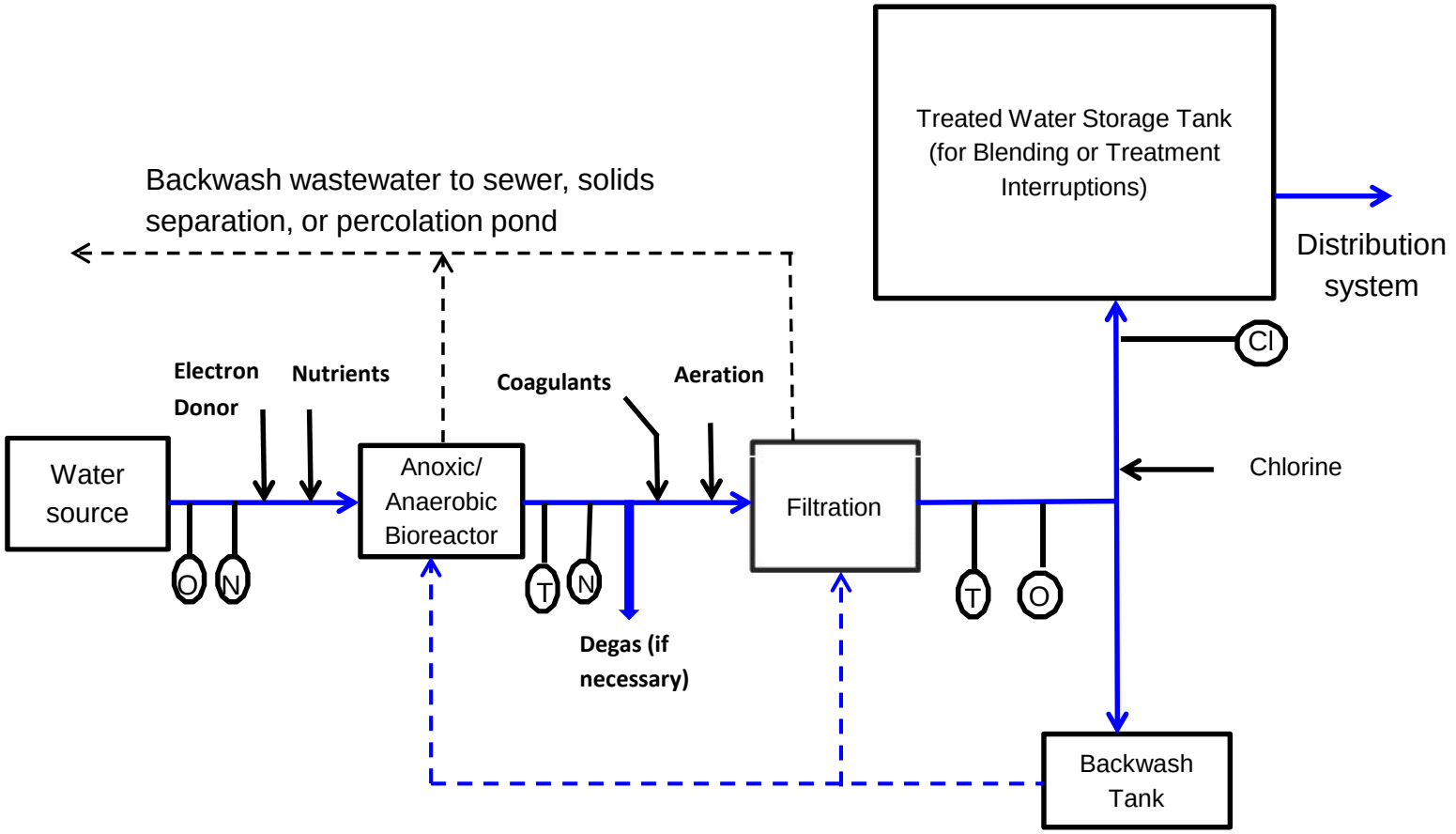
Pilot Testing Phases

- Phase I: Biological Acclimation
- Phase II: Optimization
- Phase III: Sustained Removal
- Phase IV: Robustness Testing

General Demonstration Approach

- Start-up Procedures (ramp-up, recirculate, pump-to-waste)
- Steady State Operation (optimization, flow rates, chem. dose)
- Chemical Interruptions
- Water Flow Interruptions (intentional, hours to days)
- System Recovery
- Site-specific testing is required
- Key concerns:
  - During start-up or system upset, will/can water be discharged?
  - What will be the source of drinking water for customers during the time period? Storage?

Reliability Features



Online Instruments

T = Turbidimeter
N – Nitrate analyzer
O = Oxygen analyzer
Cl = Chlorine residual analyzer

Chemical feed pumps with flow sensor or mag meters with be important

Questions?

Eugene Leung

Eugene.Leung@cdph.ca.gov

(510) 620-3460