Nitrate Treatment Technologies for Drinking Water

Technology Update 2016 for
Central Coast Regional Water Quality Control Board

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Division of Drinking Water
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Presentation Goal

- Highlight the latest treatment technologies from around the state for nitrate treatment
- Bring awareness to key issues that must be addressed or considered in order to implement these technologies.
- How they differ from existing (traditional) treatment technologies already in the marketplace.
- Project status for these technologies.

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Presentation Outline

- Nitrate Maximum Contaminant Level
  - Associated Health Risks
  - Compliance Determination for public water systems
  - Nitrate Treatment Options
- Optimized Ion Exchange Treatment
- Biological Treatment
  - Different Reactor Designs
  - Targeting Nitrate, Perchlorate, and more…
  - Performance Requirements
  - Demonstration / Full Scale Projects
- Point-of-Use as an interim solution

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Nitrate Maximum Contaminant Level

- Effective July 16, 2015, Nitrate is now reported as Nitrate as Nitrogen
- Nitrate MCL is 10. mg/L as N
- Nitrite MCL is 1. mg/L as N
- The change in reporting unit does not affect the nitrate MCL and brings us inline with the rest of the country. 10. mg/L as N is substantially the same as 45 mg/L as NO_3 (nitrate)

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Nitrate Maximum Contaminant Level (2)

- Acute Health Risk Contaminant = Significant Health Effects by even ingesting water over MCL for a short period of time (Tier 1 violation)
- Vulnerable populations are: infants below the age of six months & pregnant women
- DDW requires water systems providing treatment for nitrate must provide treated water that meet the drinking water standard at all times.

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Typical Treatment Target

- 80% of MCL as a starting point for treatment target.
- May be adjusted up with good record.
- Treatment target can be achieved by blending of treated water with by-pass flow or treating 100% of water.
- On-line nitrate analyzer has allowed water system to blend and treat more effectively.
- Analyzers require skilled technicians to maintain and is expensive. (~$16K)

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General Background on Ion Exchange

- Proven technology
- Used successfully for nitrate, arsenic, perchlorate
- Different Resin Types

Technical Considerations

- Performance (new vs. regenerated)
- Nitrate peaking (non-nitrate selective resin)
- Regeneration method
- Treatment residual
- Disinfection By-products (nitrosamines)

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Nitrate Treatment Options

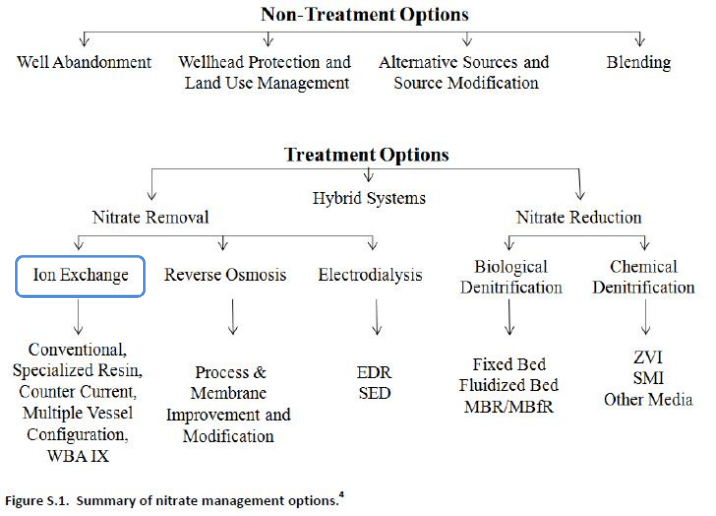
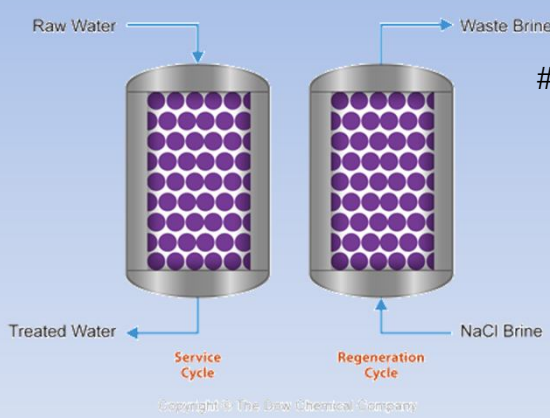


Figure S.1. Summary of nitrate management options.[4]

Source: Drinking Water Treatment for Nitrate, Technical Report 6 by UC Davis & Jacobs Engineering Group http://groundwaternitrate.ucdavis.edu/

Ion Exchange Treatment



#1 issue - Brine Disposal

Key Innovations for Brine Volume Reduction:

1. On-line analyzer driven operation - regenerate only when exhausted
2. Improved hydraulics
3. Sulfate return to reduce brine volume
4. Reuse of re-generant

Similar to household softener but with a different type of resin.

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Optimized IX (100-125 gpm)

Containerized Treatment Plant allows off-site assembly and minimize engineering.

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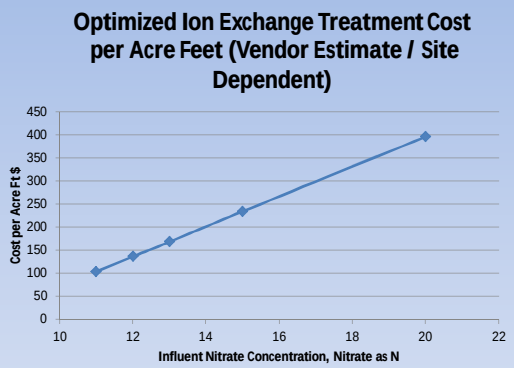
Ion Exchange Treatment Cost

- Capital Cost
- Salt Cost
- Brine Disposal
- Operations
- Maintenance



- As incoming nitrate concentration increases, the salt cost and brine disposal cost increase significantly, especially for inland systems.

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Treatment Performance Requirements & Other Considerations

- Consistently below nitrate and nitrite MCL
- Continuous disinfection
- To ensure treatment reliability, treated water nitrate monitored continuously
- Operator certification = T2 Facility (minimum)

Ion Exchange Treatment is a mature technology, but may be too difficult for small water systems to operate. A possible solution for a small systems is technical consolidation of systems where the treatment plant is remotely monitored and serviced by a WTP operator.

Clarity on local Regional Board's position on ion exchange treatment will help in technology deployment - chloride loading and brine disposal.

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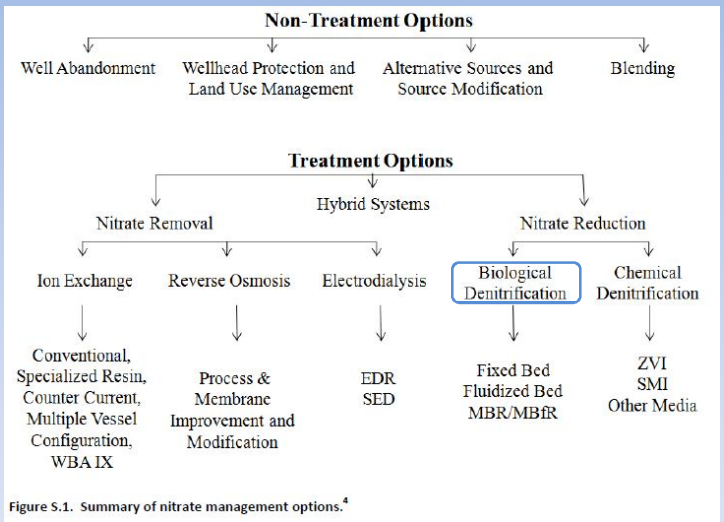
Nitrate Treatment Options



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Biological Treatment
Process Fundamentals for Nitrate (and Perchlorate)

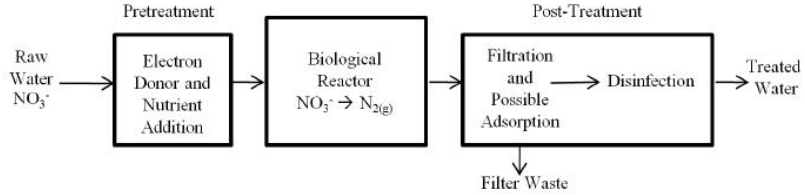

Figure 12. Biological denitrification schematic.

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

Denitrifying bacteria breakdown nitrate to nitrogen gas.

Key Benefit: There is no concentrated waste stream.

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

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Technology Variations

- Bioreactor design
  - Fluidized Bed (Up Flow)
  - Fixed Bed (Down Flow)
  - Continuous Stir Tank Reactor (CSTR)
  - Biocatalysts - bacteria contained inside capsules
  - Membrane Biofilm Reactor (Rolled-up Membrane)
  - No one has proposed membrane bioreactor yet (popular for WW treatment)
- Electron donor used (Acetic acid, ~~ethanol, H_2~~)
- Nutrient, site specific (Phosphorous)
- Generally, bioreactors are not pre-seeded and rely on naturally-occurring indigenous bacteria
- Single-pass vs. multi-pass (recirculated) reactor

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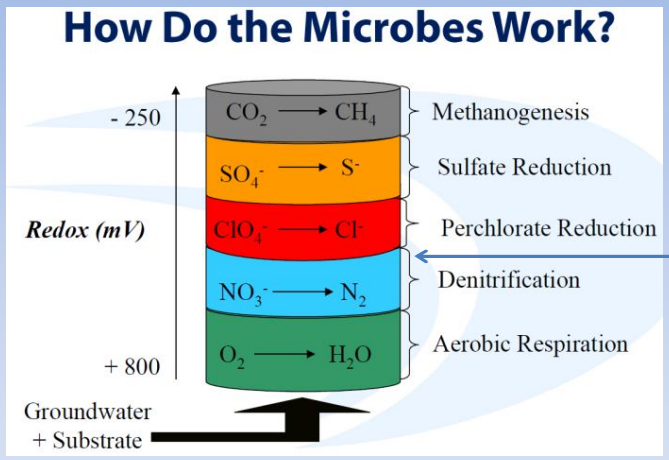
Reaction Sequence

(Illustration from Todd Webster, April 22, 2009 presentation to WTC – Envirogen)



Contaminants with Acute Health Risks... Nitrate and Perchlorate

For Nitrate Treatment, an on-line analyzer is used to ensure treatment is effective.

During extended off-cycles, biological process in filters may operate in Sulfate Reduction range and may generate sulfides.

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Key concerns for Biological Treatment

- Biological treatment is a living treatment process and prefers steady state (continuous)
- During start-up or system upset, where can the off-spec water be discharged?
- What will be the source of drinking water for customers during start-up or upsets?
- Is there a storage tank?
- During system upset, incomplete reduction may occur and can result in excess nitrite?

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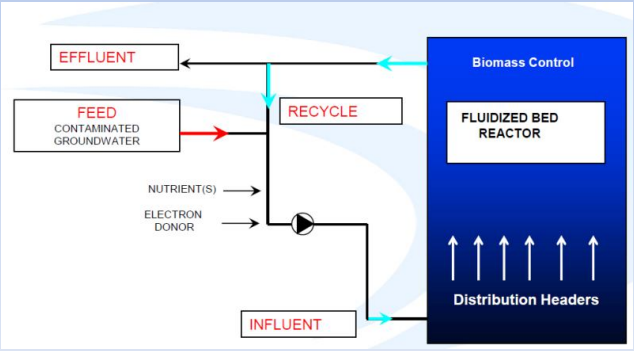
Key concerns for Biological Treatment (2)

- How quickly can the treatment system recover from chemical or water flow interruptions?
- Site-specific testing is required

Fluidized Bed Process.

Water is recirculated in reactor.



From: Envirogen

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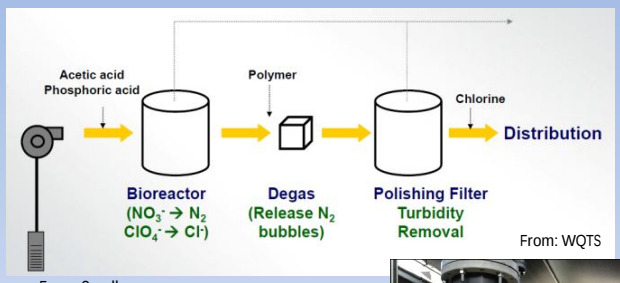
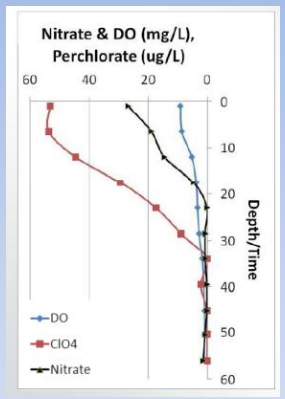
Fixed Bed Process Diagram



From: Carollo



From: Carollo

Compared to Fluidized Bed, Fixed Bed Process is a single pass process.

Two consecutive GAC filters are used as the medium for bacteria growth and as a polishing filter.

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City of Delano

- Fixed Bed Reactor (FXB)
- Well 35 is 570 gpm
- 200 gpm treated flow + 370 gpm by-pass
- Full scale demonstration facility about to start up now.

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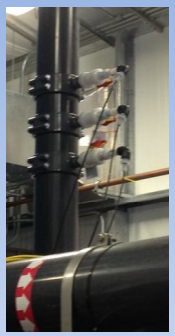
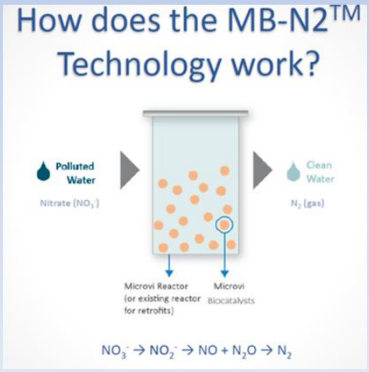
City of Delano (2)



Biocatalyst System

- Sunny Slope Water Company
- Vendor / Water System funded project
- Single pass system

From: Microvi



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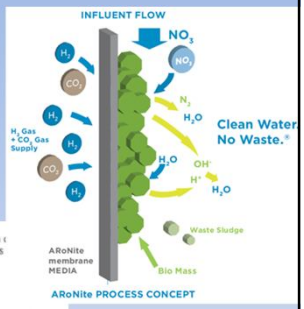
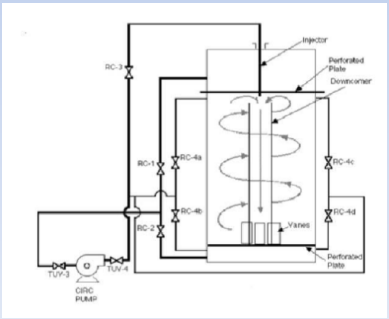
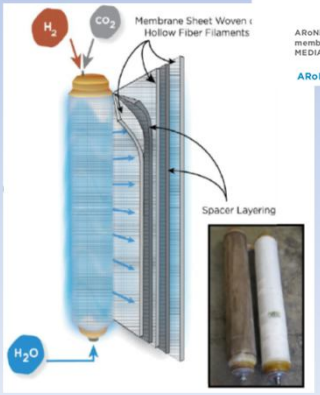
CSTR and Membrane Biofilm Reactor

CSTR Reactor with recirculation sponges







Polypropylene Hollow Fiber Membrane

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Treatment Performance Requirements

- Consistently below nitrate and nitrite MCL
- Excess biomass removed
- Low turbidity water for effective disinfection
- Continuous disinfection
- Treated water is re-aerated to provided dissolved oxygen
- Comply with all other drinking water standards (disinfection by-products, taste and odor, etc.)
- Corrosion control is provided, if necessary

- To ensure treatment reliability, on-line instruments are used to monitor chemical feeds and various treated water parameters. Automatic shutdown is required.

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Other Considerations

- Operator certification = T3 Facility (minimum)
- Lack of drinking water operators, designers and regulators familiar with this family of technology
- Long-term treatment reliability is not known
- Many groundwater systems have only one source and/or no storage tanks (require 100% on-spec)
- Intermittent operation
- Projects at Delano, West Valley and Supply Slope have back-up supplies and will help provide valuable experience

Biological Treatment is an emerging group of technology in drinking water applications. We need more experience before using it for smaller systems.

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Delano Project Cost *(Vendor Estimates)*

- Delano full-scale treatment facility at Well 35
- Typical operating flow for the well is 570 gpm
- Facility is designed to treat 200 gpm
- Construction cost: $2.6 million (does not include engineering design or engineering services during construction, legal, or administrative costs). Cost includes treatment facilities enclosed in a building.
- Chemical costs are based on the raw water nitrate concentration (10 mg/L NO3-N) and a biottta effluent NO3-N of 1.0 mg/L
- $180 - $220/AF treated to 1 mg/L nitrate as N
- $80 - $100/AF delivered
- Total project cost = $5+ Million Dollars

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Current Status (as of 3/2016)

Treatment Technology (Company)	Year Conditional Acceptance Granted / Challenge Testing Completed	Current or Recent Projects in California Red = LIVE project
Fluidized Bed Reactor (Envirogen)	2002	**West Valley Water District** 2000 gpm perchlorate WTP completed (San Bernadino)
Fixed Bed Reactor (Carollo)	2004 and amended in 2011	Western Municipal – Pilot only, **City of Delano** 200 gpm (570 gpm well) Full scale nitrate WTP (Kern) Parallel Plant at WVWD
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 + Evoqua)	2015	West Valley Water District (San Bernardino)
Biocatalyst (Microvi)	2015	**Sunny Slope Water Co.** nitrate WTP (Los Angeles)

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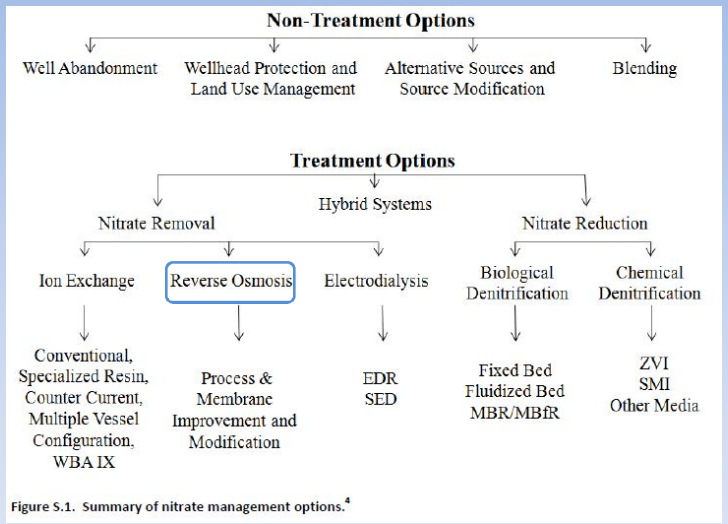
Nitrate Treatment Options



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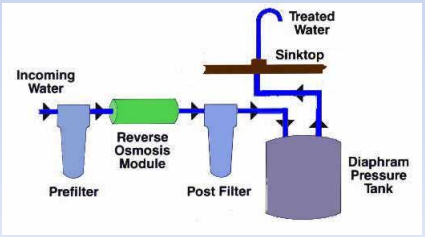
Point-of-Use Device - Reverse Osmosis

- Reverse Osmosis based Point-of-Use treatment devices are likely the best option for nitrate and other contaminants for private homes or very small water systems
- Certified home treatment devices available
- Adequate feed pressure is critical if >2x MCL
- Proper maintenance, battery replacement and change-out of components are critical
- TDS used as surrogate of membrane health
- Annual laboratory testing of product water quality is recommended



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Reverse Osmosis (RO) based POUs Discharge Considerations

- Useful option for very small water systems as interim solution to provide safer drinking water for a variety of contaminants
- Consolidation as long-term solution
- RO POUs are likely the only affordable solutions for private homes and non-public water systems
- Need consistency on acceptance of use by local Regional Boards

If the entire home is defined as a system, there will only be a slight difference in contaminant concentration in the septic system (with or without RO POU treatment.)

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Technology Comparisons

	Biological	Ion Exchange	RO Point-of-Use
Full-Scale Use	3 in progress	Multiple	Interim / Small WS
Residuals	Sludge/Biosolids/ Washwater	Waste Brine	Concentrate* (Very low strength)
Water Recovery	Near 100%	97% Optimized: 99.7%	Varies 3:1 ratio
Advantages	• No brine waste • Multi-contaminant	• Proven technology • Multi-contaminant • Package plants avail.	• Quick deployment • Multi-contaminant • TDS reduction • Targeted treatment
Disadvantages	• Complex Treatment T3 • Multiple chemicals (4) • Risk of nitrite formation • Post-treatment reqmnts • Risk of treatment upset • Large Foot-print	• Brine waste disposal • Chloride loading • Complex System T2	• Reject water is wasted • Require access to inside of customers homes • Increased liability
Large PWS	Yes – TMF capable (O&M?)	Yes	Too Difficult to Manage
Small PWS	Maybe – TMF, Operator No – sole source / no storage	Yes (O&M?)	Yes - <200 SC with Community Buy-In
Individual homes	No – lack TMF / high risk	Maybe – ineffective ops / brine disposal in septic	Yes – with proper O&M, education and testing

For discussion purposes only. TMF = Technical, Managerial, Financial Capacity

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Closing Thoughts

- There is no silver bullet - a combination of different treatment technologies; regionalization and consolidation will be needed to solve this problem
- Nitrate Treatment Technologies are complex to operate
- Technical, Managerial and Financial (TMF) Capacities and O&M Costs (affordability) remain as the major challenges for water systems
- Interim solutions are also needed as the above will require planning and coordination

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- Questions?

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