Treatment technologies for removing contaminants of emerging concern:

1,4-dioxane, 1,2,3-TCP, PFOA/PFOS, perchlorate, and Cr6

Chino Basin Water Quality Colloquium
May 2, 2019

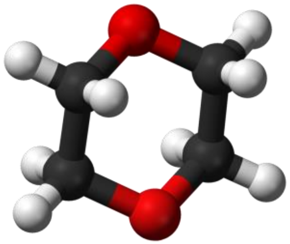
Nicole Blute, PhD, PE

Agenda

- Review emerging contaminants of concern in the Chino Basin
- Present treatment options
- Discuss factors affecting treatment selection and design

1,4-Dioxane

Background



Sources	Used as a solvent and stabilizer in the past
Chemical Characteristics	Highly soluble in water resulting in significant groundwater transport Low adsorbability to carbon Relatively resistant to biological treatment options

California Notification Levels: PFOA – 14 ug/L, PFOS – 13 ug/L

1,4-Dioxane AOP Treatment

UV light reacts with an oxidant (peroxide, ozone, hypochlorite) for form hydroxyl radicals (•OH)

•OH radicals are highly reactive, including with organic constituents of concern

1,4-Dioxane AOP Treatment

Key Design Parameters

- Elevated nitrate levels can result in scavenging and production of nitrite for medium pressure UV
- TOC and UV transmissivity are key
- Buffer capacity of water typically makes UV/chlorine more costly unless treating RO permeate
- Residual peroxide quenching (GAC or chlorine)

$Cl_2 + H_2O_2 \rightarrow O_2 + 2\ HCl$

Approximately 2:1 Cl_2: H_2O_2

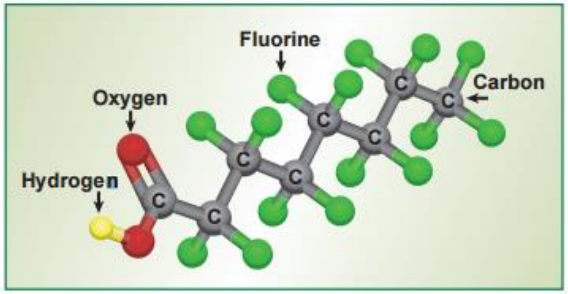
1,4-Dioxane Emerging Technology - Resin

Ion Exchange with Regeneration

- Industrial applications, fairly small scale (100-200 gpm)
- Requires steam regeneration of resin on site

PFOA/PFOS

Background



Sources	Anthropogenic compounds used in many consumer products (Teflon, Scotchgard, Gore-tex), fire fighting foams
Chemical Characteristics	Mobile in water Very persistent in the environment (high solubility, low volatility High adsorbability to carbon for long chains; less for short chains Biological degradation minimal

California Notification Levels: PFOA – 14 ng/L, PFOS – 13 ng/L

PFAS Family of Chemicals

TERMS

PFC = Perfluorinated Compound

PFAS = Perfluoroalkyl or Polyfluoralkyl Substance

PFOA = Perfluorooctanoic Acid
$C_8HF_{15}O_2$

PFOS = Perfluorooctane Sulfonate
$C_8HF_{17}O_3S$

GenX = $C_6H_4F_{11}NO_3$

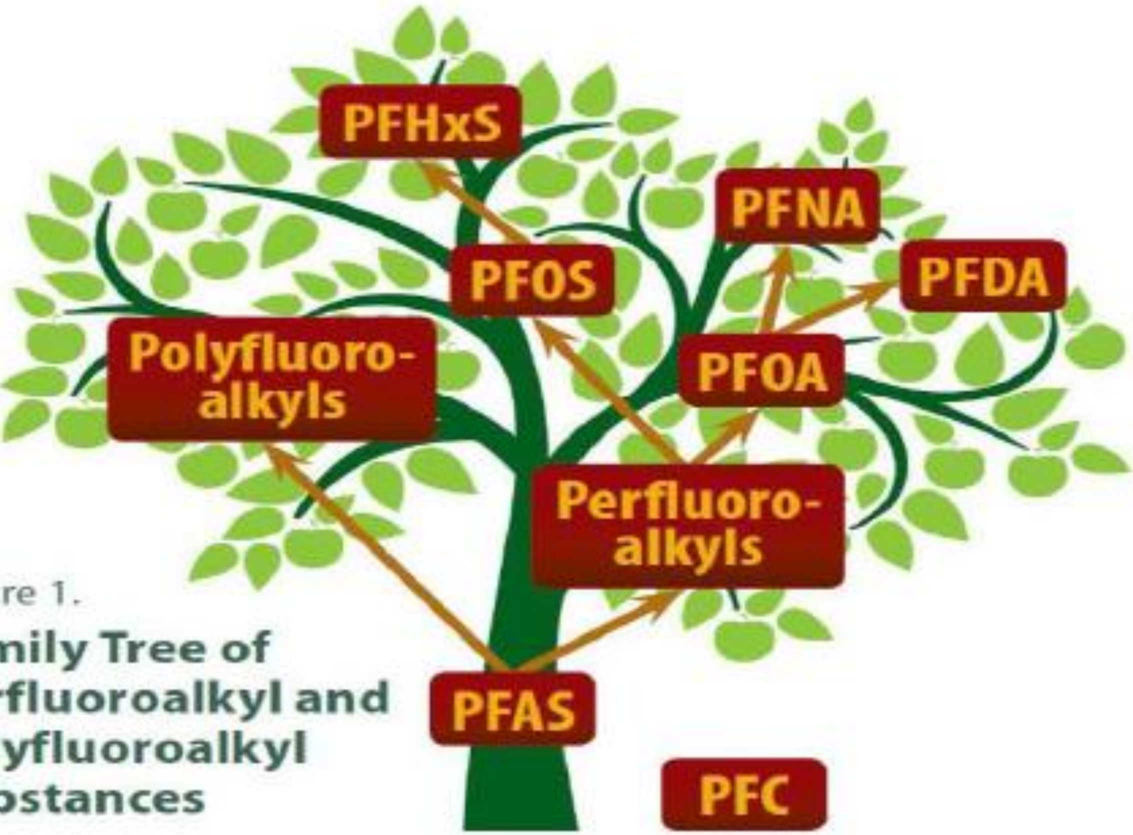


Figure 1.
Family Tree of Perfluoroalkyl and Polyfluoroalkyl Substances

Source: https://www.atsdr.cdc.gov/docs/17_278160-A_PFAS-FamilyTree-508.pdf

Treatment Options for PFOS and PFOA

Effectiveness of treatment depends on concentration, raw water quality, and other variables

$$

RO NF
- 90% removal

GAC
- >90% removal

Anion Exchange
- 10->90% removal, depending on water quality

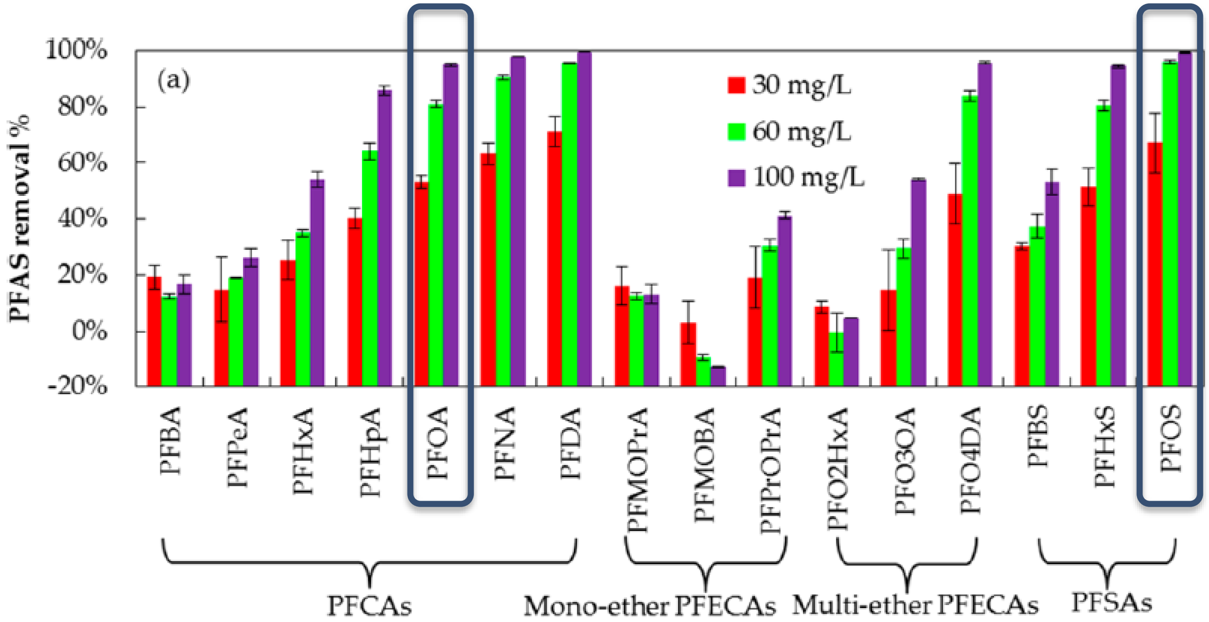
X

Advanced Oxidation
- Not effective

PFOA/PFOS GAC Treatment

Key Design Parameters

- GAC is effective for longer-chain molecules
- Removal to non-detect levels may require polishing step – e.g., GAC or IX



Ref: Sun et al., 2016

PFOA/PFOS Persistence

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Public health experts aim to stop spreading of sludge

Fred Stone says he can't sell milk from his herd because of exposure to PFAS, chemicals linked to cancer that were found in the sludge he spread on his fields for decades.

BY **KEVIN MILLER** STAFF WRITER

Fred Stone holds Lida Rose, one of his brown Swiss cows, on his Arundel dairy farm before a news conference Tuesday that was held to raise awareness about PFAS chemical contamination in his fields and cows resulting from municipal sludge he had spread from 1983 to 2004. Lingering contamination in his herd is forcing him to dump the milk his cows produce. *Gregory Rec/Staff Photographer*

1,2,3–Trichloropropane

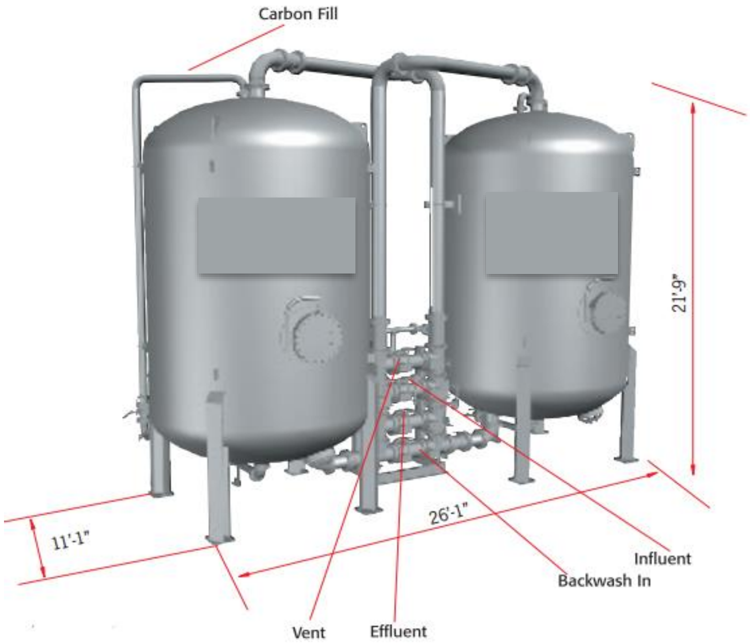
Background

Sources	Primarily from an impurity in fumigants Also reported to be an anthropogenic compound associated with degreasing and cleaning agents
Chemical Characteristics	Mobile in water Persistent in the environment (high solubility, low volatility)

No federal MCL, but California has an MCL of 5 ng/L

1,2,3-TCP GAC Treatment

- GAC listed by DDW as the only best available technology
- Commonly lead-lag configuration to maximized carbon utilization
- GAC removes 1,2,3-TCP to less than the DLR



1,2,3-TCP Emerging Technology – Biological Treatment

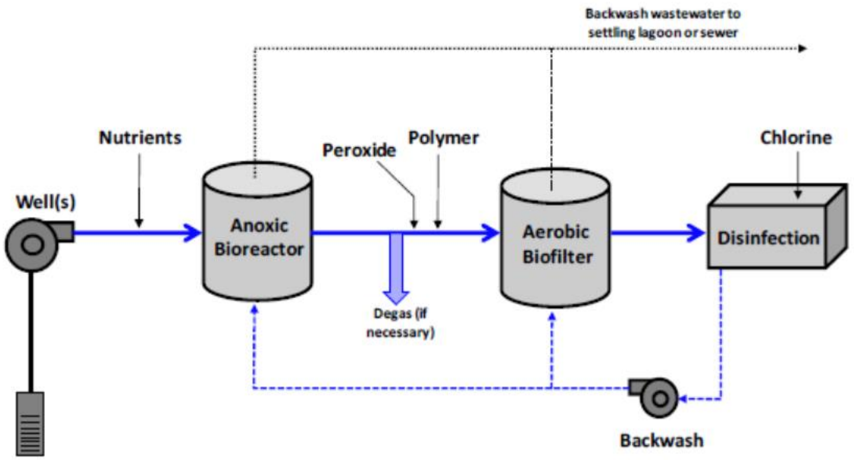


Figure 1: biottta™ System Process Flow.

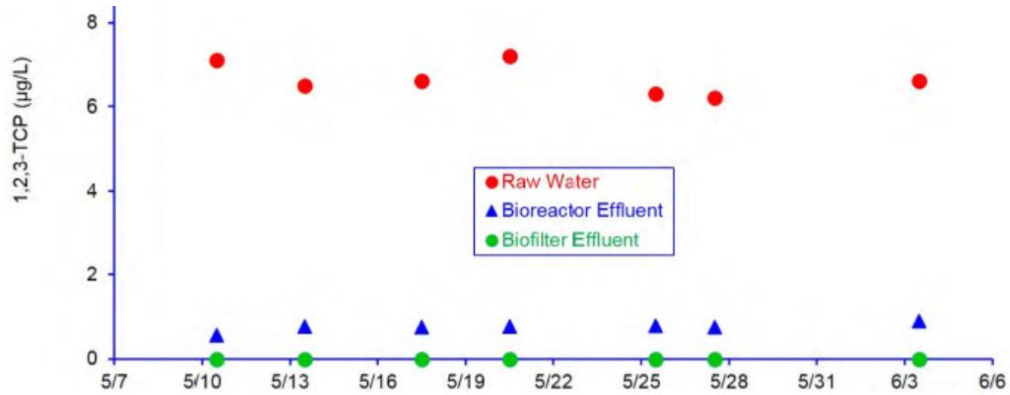
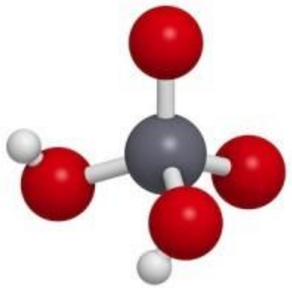


Figure 28: 1,2,3-TCP Concentrations across the Pilot System during Steady-State Operation

Carollo, 2016.

Chromium

Background



Sources	Naturally occurring from minerals Anthropogenic
Chemical Characteristics	Inorganic anion Cr6 primary aqueous species; Cr3 forms precipitate Persistent in the environment (high solubility, low volatility) Biological degradation is possible

Former Cr6 MCL of 10 ug/L; new MCL expected.

Chromium Treatment

Best Available Technologies

Weak-Base Anion Exchange (WBA)

Strong-Base Anion Exchange (SBA)

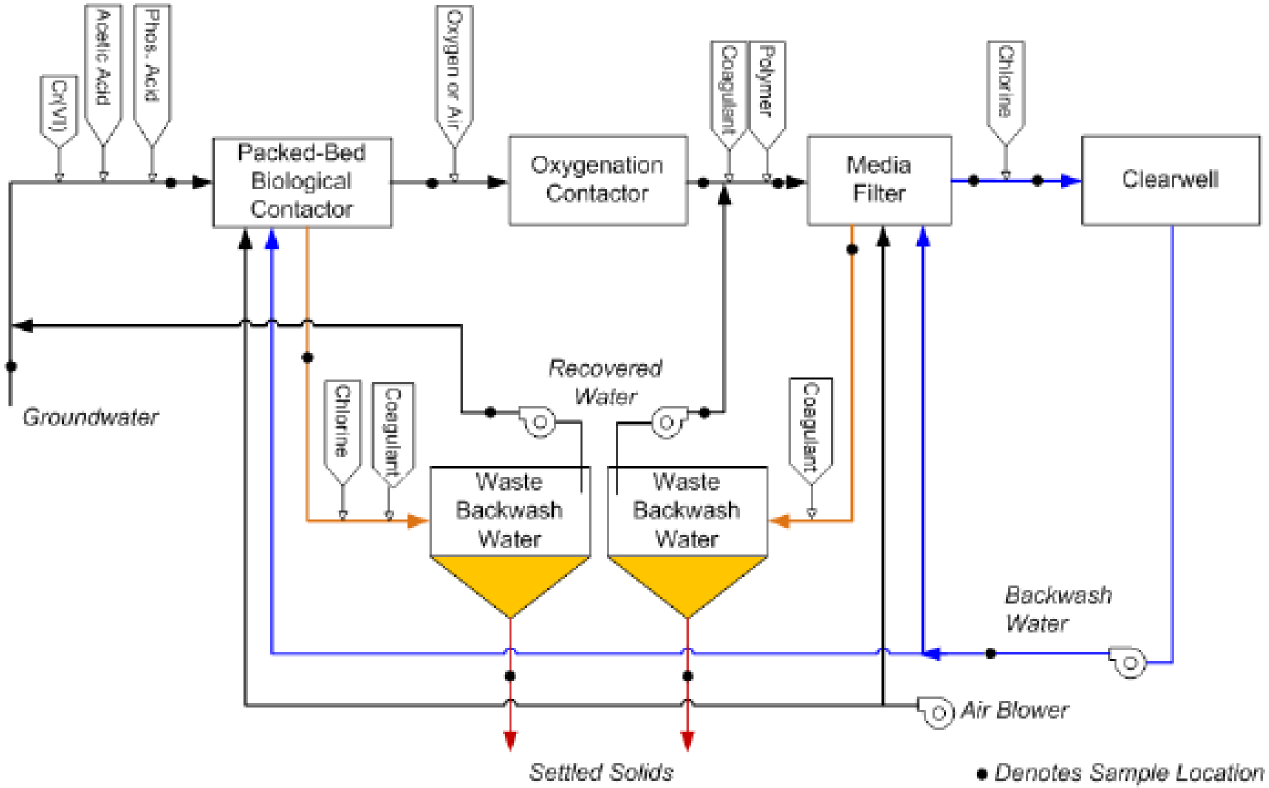
Reduction Coagulation Filtration (RCF or RCMF)

Reverse Osmosis (RO)

Alternate Technology – Stannous Chloride

- Salt made of tin and chloride ($SnCl_2$)
- No regulatory guidance on tin
- Reduces Cr(VI) to Cr(III) and forms a precipitate that can be filtered
- Could be used with filtration similar to iron in RCF process
- Concern about long term fate of tin and chromium particles in the distribution system – more study is needed

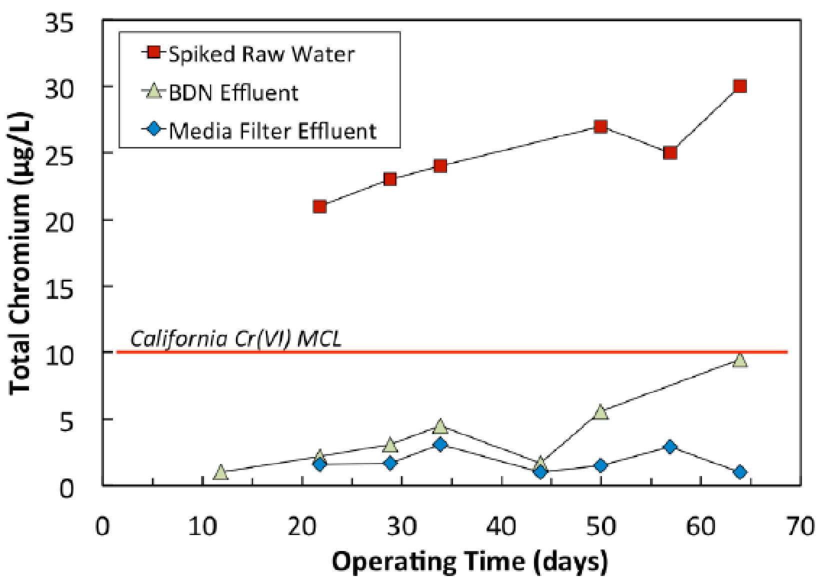
Alternate Cr6 (and nitrate, perchlorate, and VOC) Technology – Biological Treatment

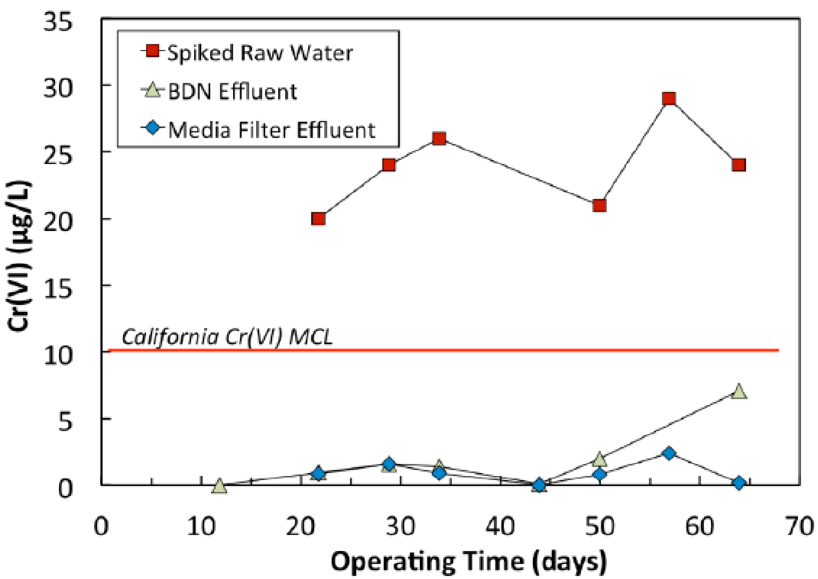


LA County District Well 37-01

WQTS, 2014. WRF 4470.

Alternate Cr6 Technology – Biological Treatment





(1) Reduction from Cr(VI) to Cr(III): $Cr^{6+} + 3e^{-} \rightarrow Cr^{3+}$

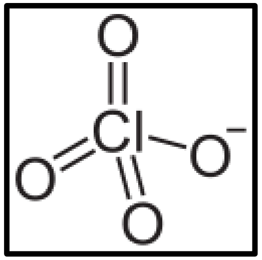
(2) Precipitation of Cr(III): $Cr^{3+} + 3OH^{-} \rightarrow Cr(OH)_{3(s)}$

(3) Coagulation & Filtration of $Cr(OH)_{3(s)}$ *precipitate*

WQTS, 2014. WRF 4470.

Perchlorate

Background



Sources	Solid rocket fuels and propellants, Chilean fertilizers, background
Chemical Characteristics	Inorganic anion Persistent in the environment (high solubility, low volatility) Low adsorbability to carbon Biological degradation is possible

California MCL 6 ug/L; DDW likely to decrease the DLR to determine if regulation to a lower concentration is warranted.

Perchlorate – Ion Exchange Treatment

Removal by Ion Exchange

Regenerable SBA

Perchlorate-Selective Resin

Summary of Treatment Approaches

	GAC	AOP	IX	RCF	Biolog-ical	RO
1,4-Dioxane	✓ (quench-ing)	✓				✓
1,2,3-TCP	✓				✓	✓
PFOA/PFOS	✓		✓			✓
Perchlorate			✓		✓	✓
Cr6			✓	✓	✓	✓

BAT or leading technology

Can be effective but not BAT

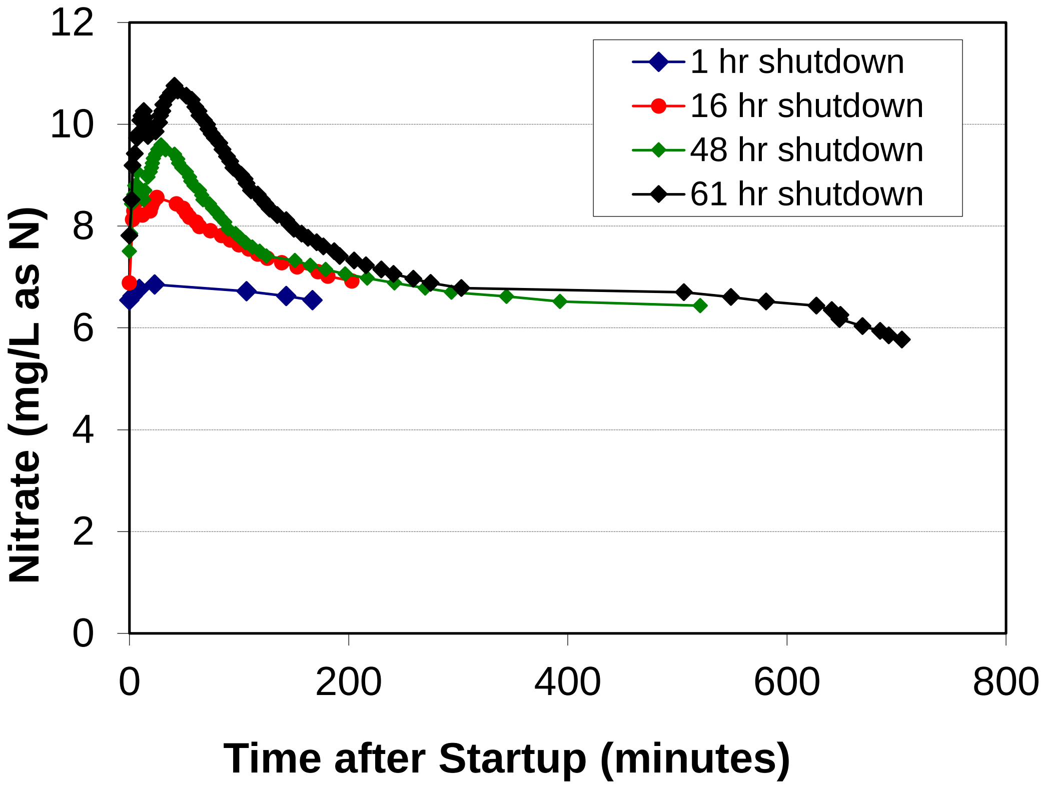
Many Roads Lead to GAC…

1,2,3-TCP

PFOA/PFOS

1,4-Dioxane
(peroxide quenching)

GAC Operations Needs to Consider Nitrate



Options:

- Online analyzer with filter-to-waste or blending
- Minimize down time
- IX downstream of GAC if necessary

Questions?

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