

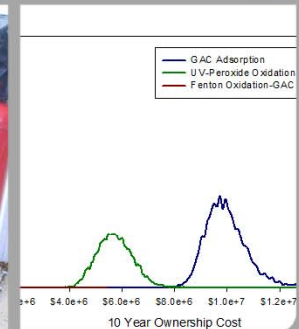
Inensitive Munitions are Different *Environmental Management and Cost Implications of IM Articles*

Jared L. Johnson, P.E.

Research Environmental Engineer

US Army Engineer Research and Development Center

24 August 2017



Innovative solutions for a safer, better world

US Army Corps
of Engineers®

Insensitive Munitions

- Required for increased soldier safety and prevention of material losses (DoDI 5000.02, 10 USC 2389)
- Articles containing insensitive formulations are entering Army inventory



Camp Doha (1991) – 51 Soldiers injured and 102 vehicles damaged or destroyed



Inensitive Munitions

- Different chemical properties lead to changes in environmental management

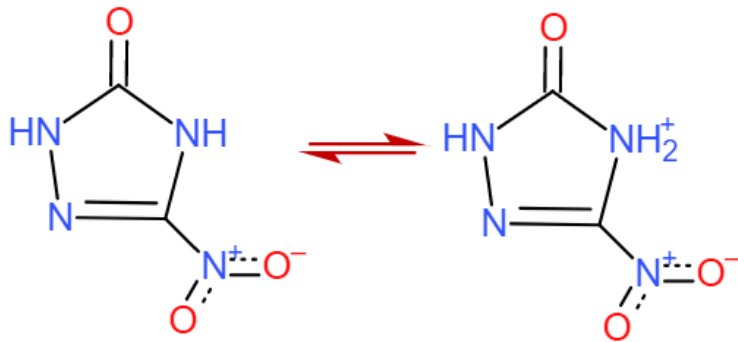
Redwater/Pinkwater

- Mixed wastewater containing TNT, RDX, DNTs, amino-NTs, etc.
- Contains an upper limit of ~200 mg/L total explosives
- Historically treated by GAC adsorption at a cost of \$0.03-0.07/gal

IM Process Wastewater (Yellow Water)

- Mixed wastewater including NQ and NTO, among others
- Contains an upper limit of ~20,000 mg/L total explosives
- GAC adsorption scales linearly with mass leading to an expectation of 100x increase in wastewater treatment cost
- GAC Treatability tests confirm an estimated cost of \$4.50/gal.

Inensitive Munitions

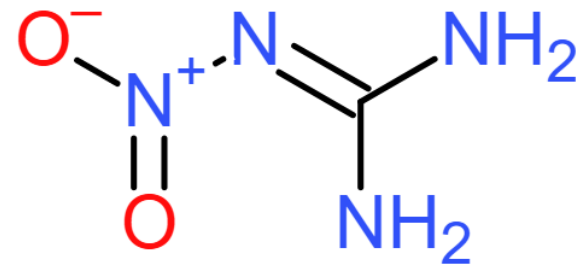


Nitrotriazolone (NTO)

Water solubility of 12 g/L

Wastewater pH of 3

Much less toxic than older explosives, but much more mobile in the environment.



Nitroguanidine

Water solubility of 3 g/L

Stable in many wastewater treatment systems

More mobile than older explosives in the environment, and phototransforms to toxic byproducts.

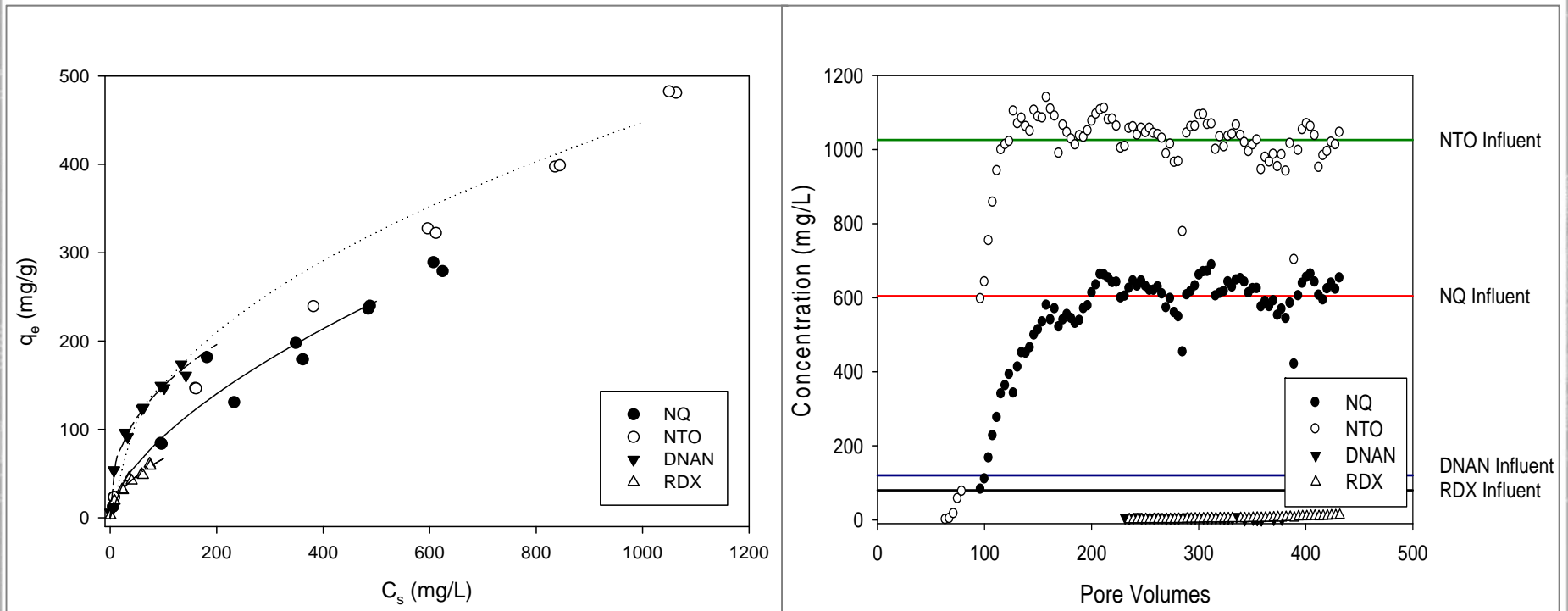
Wastewater Design and Cost Management

- IM items in production required wastewater management options
- Initiated complete review of options – including activated carbon as the base case
- Developed laboratory and pilot scale data where required
- Completed full cost estimates and preliminary designs for treatment train options

Rank (score)	Technology	Comment
1 (0.192)	Ultra Violet (UV) Peroxide	Success is highly probable. Low risk involved.
2 (0.154)	Electrochemical (EC)	
3 (0.121)	Fenton Oxidation	Success is highly probable. Some risk involved
4 (0.114)	Zero Valent Iron	
5 (0.106)	Sonochemistry with Fenton oxidation	
6 (0.094)	Reverse Osmosis (RO)	Success not guaranteed. Some risk, but possible large return on investment.
7 (0.083)	Bi-metal catalysis	
8 (0.075)	Alkaline hydrolysis	
9 (0.038)	Biological	Success not anticipated. High risk.
10 (0.023)	Persulfate	

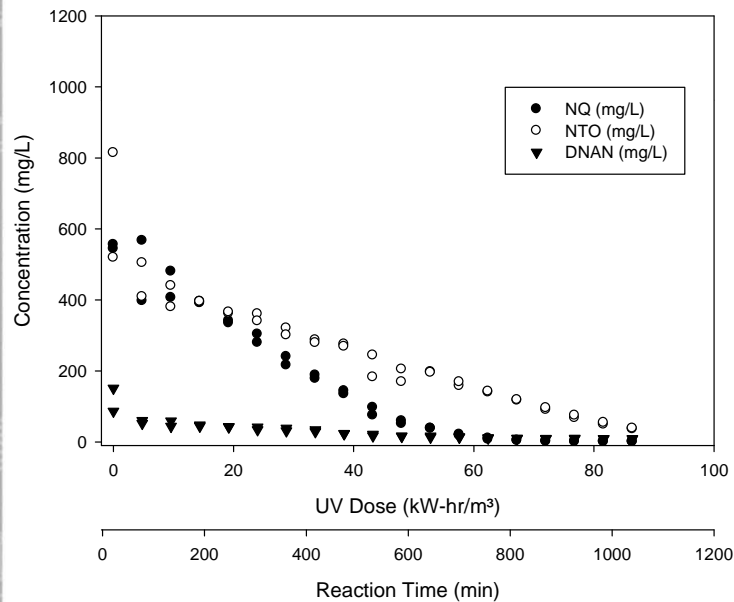
Felt et al. (2013) *Evaluation of Treatment Technologies for Wastewater from Insensitive Munitions Production*. ERDC/EL TR-13-20

Activated Carbon Adsorption



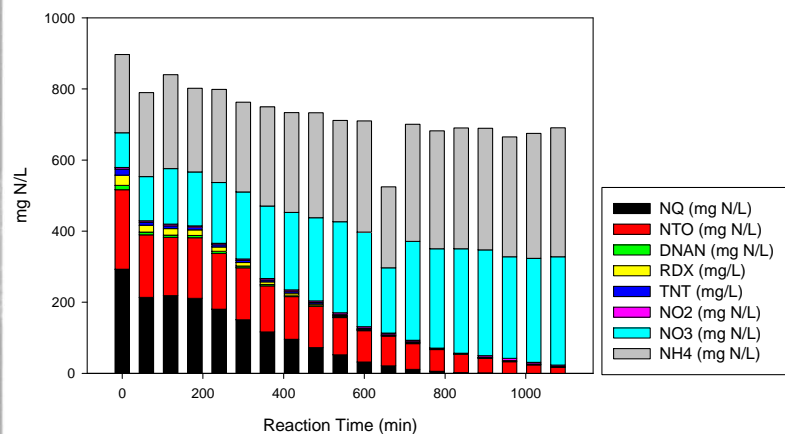
- **Column breakthrough studies using production water show limitations of adsorption**
- **High concentrations plus weaker affinities leads to low capacity**
 - **NQ: 42 mg/g**
 - **NTO: 63 mg/g**

UV-Peroxide Oxidation



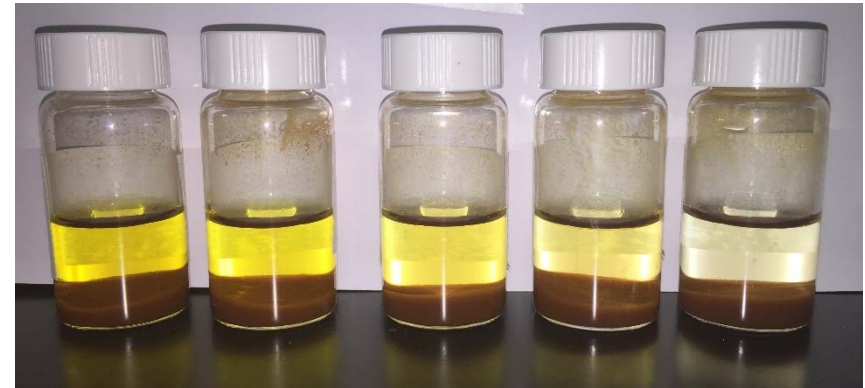
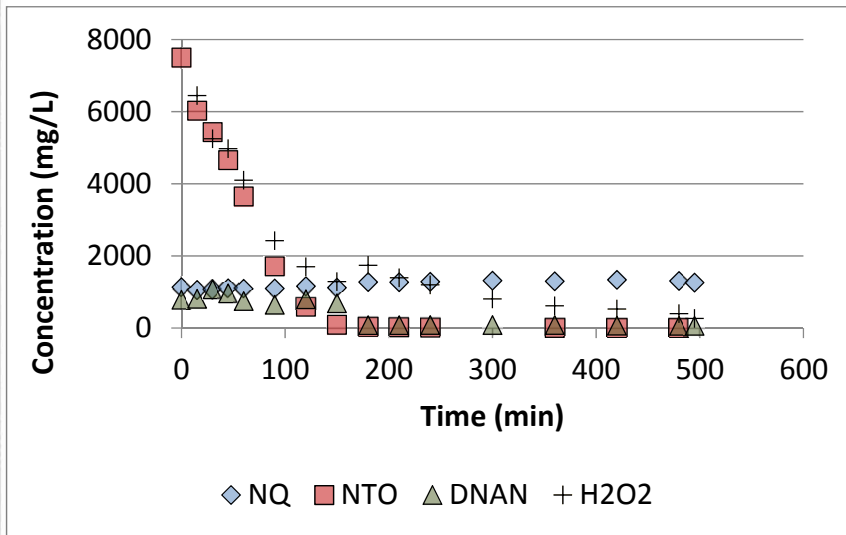
Apparent 1st Order Kinetic Rate as a Function of Applied Dose (kW-hr/m³)

NQ	M.P.	0.0349	±	0.0009
	L.P.	0.0389	±	0.0023
NTO	M.P.	0.0275	±	0.0007
	L.P.	0.0239	±	0.0016

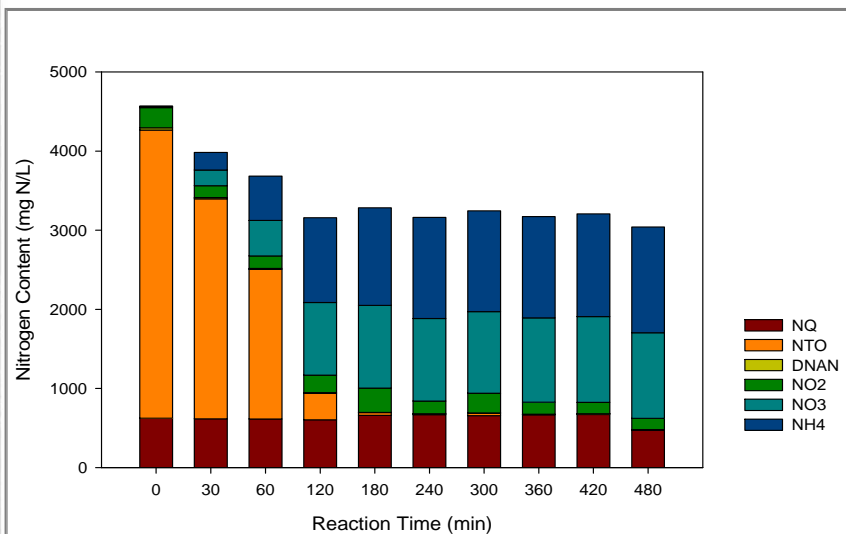


- Capable of degrading NQ and NTO
- Good kinetics in pure water
- Slow kinetics in comingled process water due to high light extinction

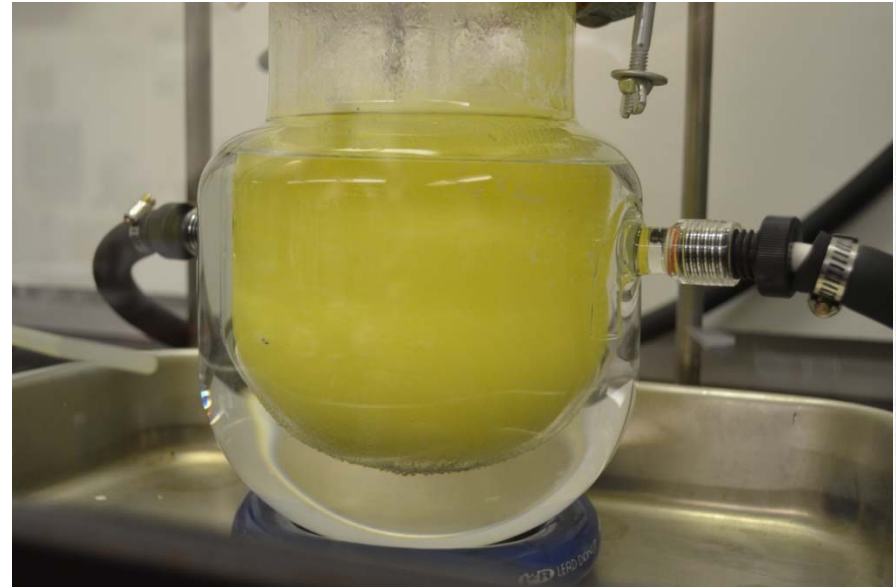
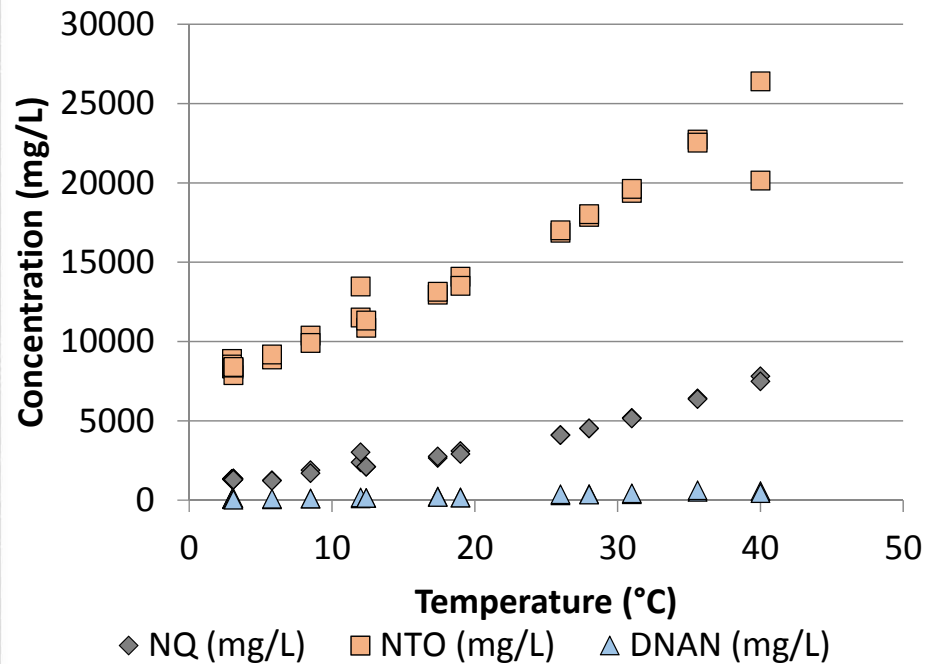
Fenton Oxidation



- Capable of degrading NTO
- NQ not degraded
- Good kinetics and lower cost compared to UV-Peroxide

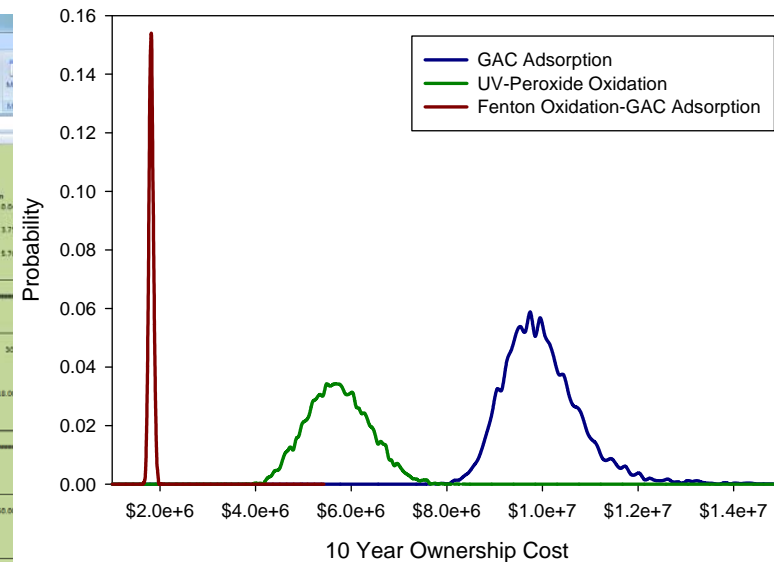
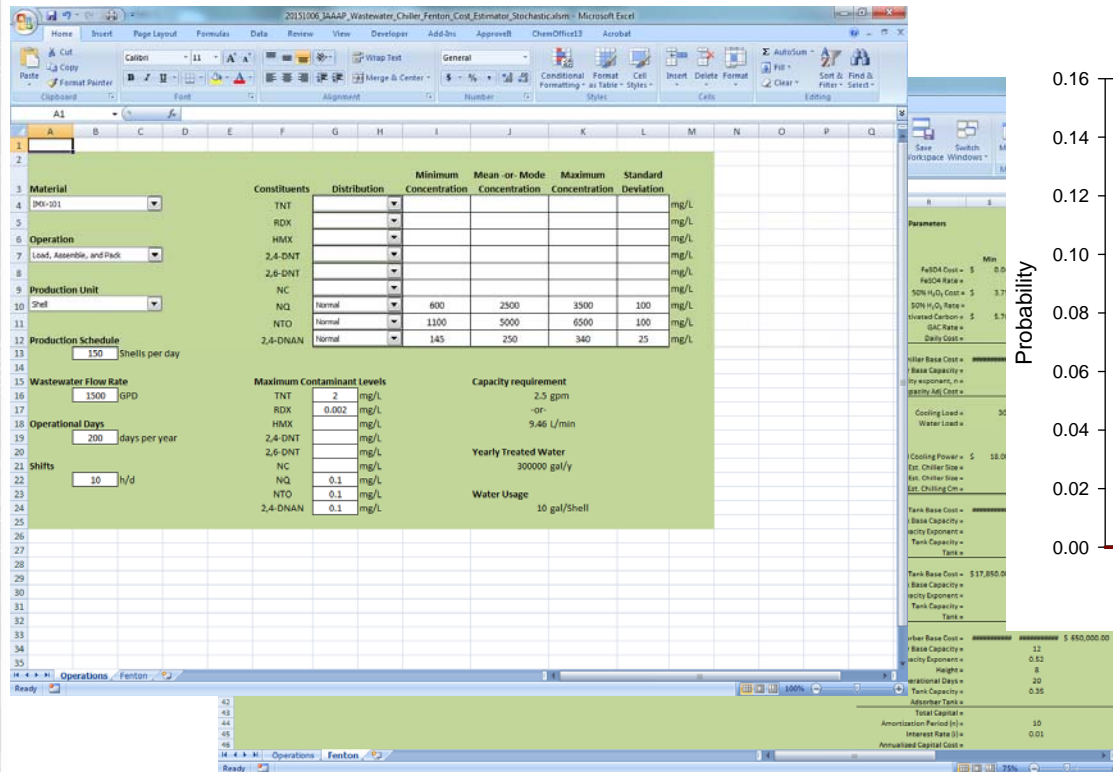


Precipitation by Cooling



- **Cooling from room temperature to 4°C removes up to 30% of the total dissolved mass**
- **Reduces downstream costs for high strength process waters**

Design Estimates and Cost Analysis



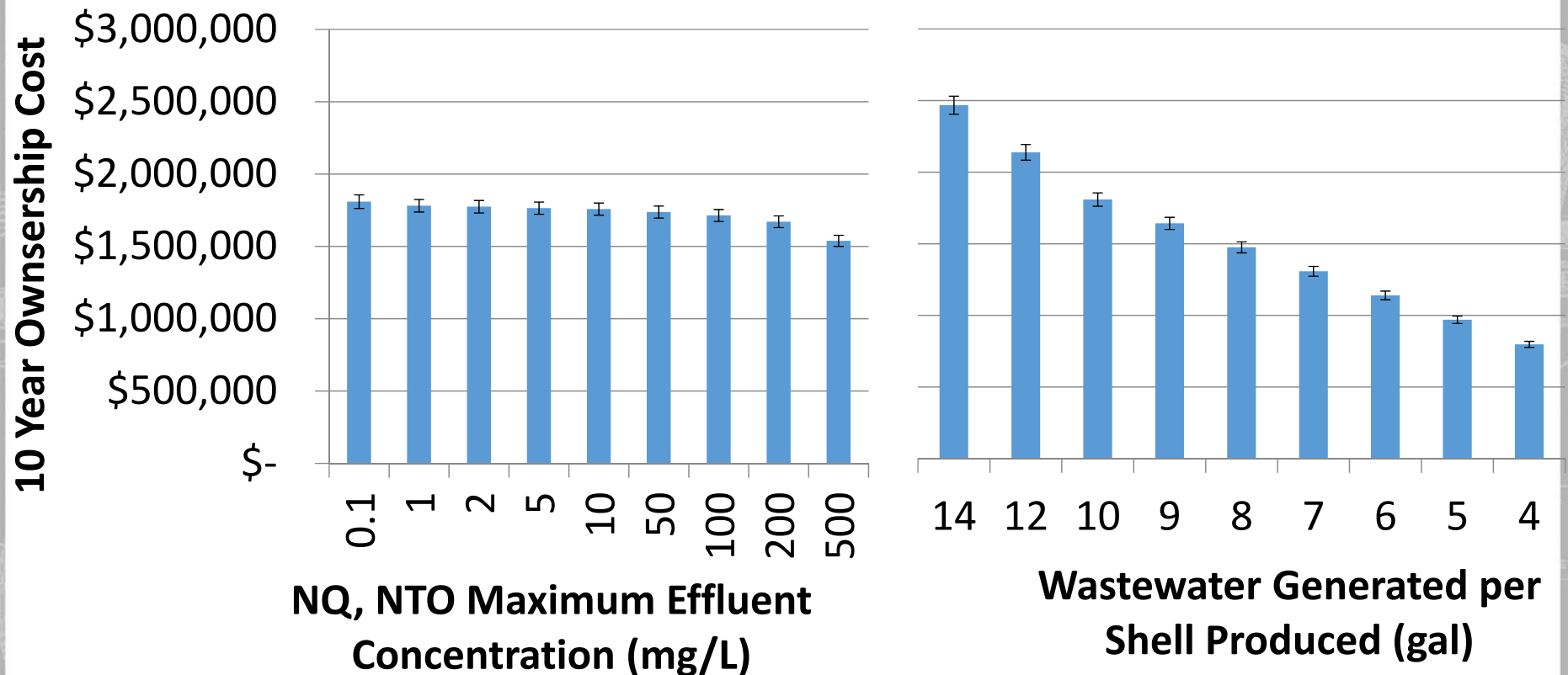
- Information to date has been incorporated into design analysis
- Includes Monte Carlo estimation of process costs and variance

Design Estimates and Cost Analysis

Design Option	Treatment Train	Operating Cost	Capital Cost	Total Cost*
1	GAC Adsorption	\$4.53/gal	-	\$4.53/gal
2	UVP Oxidation GAC Adsorption	\$1.66/gal	\$1,573,000	\$3.53/gal
3	Cooling Fenton Oxidation UVP Oxidation GAC Adsorption	\$1.67/gal	\$746,000	\$2.24/gal
4	Cooling Fenton Oxidation GAC Adsorption	\$0.56/gal	\$282,000	\$0.66/gal

*Includes operating cost and capital cost amortized across 10-yr assessment period

Where is the best return on investment?



Key Information

- Insensitive munitions will require planning for water management
- The key drivers are concentration (high solubility) and material compatibility (low pH)
- Effective management techniques exist, though they may require operational changes
- Technology demonstrations will continue in FY18 to further increase capacity and reduce costs

Questions

