

Application of Alkaline Activated Persulfate to Treat Petroleum Hydrocarbon Contamination Beneath the Active Construction of a 32-Story High-Rise Residential Tower

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ALKALINE ACTIVATED PERSULFATE

Introduction to Klozur[®] Persulfate

Klozur[®] Persulfate is:

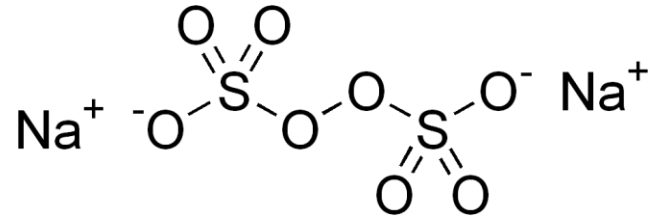
- Based on the sodium persulfate molecule
- A strong oxidant used for the destruction of contaminants in soil and groundwater
- Aggressive and fast acting chemistry with extended subsurface lifetime (weeks to months) and little to no heat or gas evolution
- Applicable across a broad range of organic contaminants
- Highly soluble in water (significant oxidant mass is smaller volumes)



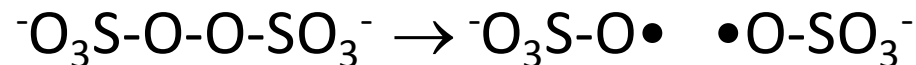
Field solubility of
more than 500 g/L
possible

Fundamental Chemistry

- Klozur[®] Activated Persulfate is based upon the persulfate anion:



- Persulfate is a peroxygen, and similar to hydrogen peroxide, it can be split at the O-O bond forming the sulfate radical:



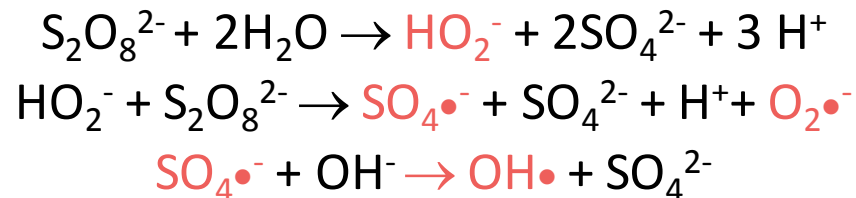
Alkaline Activation: Chemistry

- Sodium persulfate is activated when the solution is raised to pH > 10.5

- Alkaline Activation-simple version:

$$\text{pH} > 10.5 \quad \text{S}_2\text{O}_8^{2-} \xrightarrow{\text{OH}^-} 2\text{SO}_4^\bullet$$

- Alkaline Activation-complex version (Furman et al., 2010):



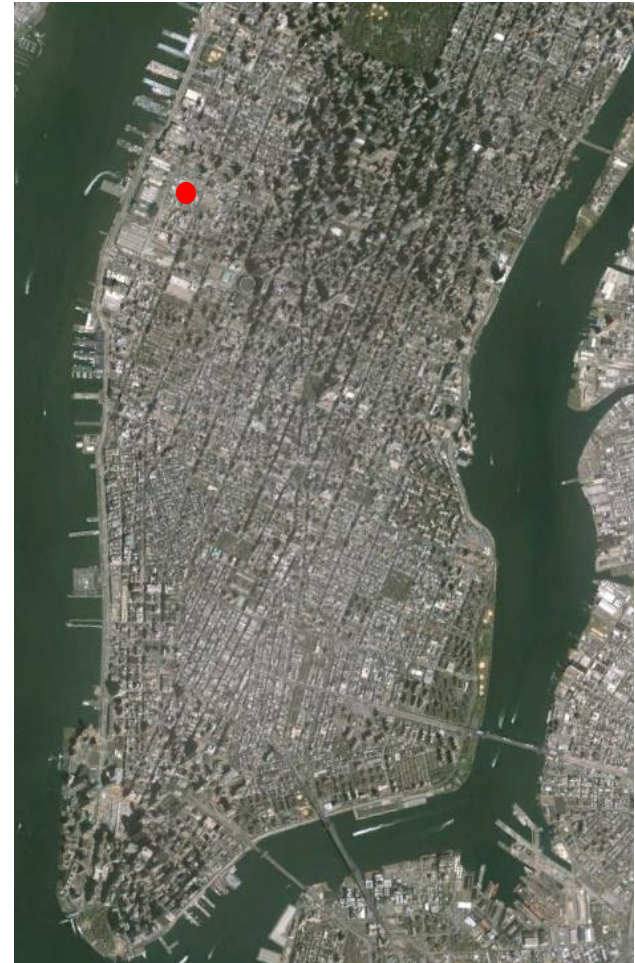
(note: $\text{H}_2\text{O}_2 \leftrightarrow \text{HO}_2^- + \text{H}^+$ $\text{pK}_a = 11.7$)

- Complex version of the reaction results in the transient oxygen species of $\text{SO}_4^{\bullet-}$, OH^\bullet , $\text{O}_2^{\bullet-}$, and HO_2^-
- Analogous to the chemistry that has been studied with catalyzed hydrogen peroxide (CHP)

SITE BACKGROUND

Background

- Located in the Chelsea neighborhood of New York City.
- Site uses included lumber yard, metal works facility, auto-repair facility, coal yard, piano manufacture, livery car service, and gasoline station.
- Leaking underground storage tanks observed at site.



Target Area

- Approximately 6,500 ft² (185 ft x 35 ft).
- Treatment Interval of 9 to 14 ft bgs.
- Sandy and silty-sandy material.



Contaminants of Concern

- Average Concentration of Petroleum Hydrocarbons:
 - 3,000 $\mu\text{g/L}$ BTEX
 - 140 $\mu\text{g/L}$ Naphthalene
 - 1,400 mg/kg GRO + DRO

- DRO and GRO up to 3,760 and 4,180 mg/kg, respectively.
- Variable GRO to DRO distribution indicated possible multiple releases.



Bench-Scale Tests

- Evaluated catalyzed hydrogen peroxide (CHP) and alkaline activated persulfate (AAP).
- CHP eliminated as peroxide decomposed rapidly even with stabilizing reagents, likely limiting subsurface distribution and resulting in rapid release of gas.
- Alkaline activated persulfate selected for effectiveness and chemical compatibility.
 - Reduced BTEX by 64-77%.
 - Reduced total TPH by 50%, with 50% percent of persulfate mass remaining.

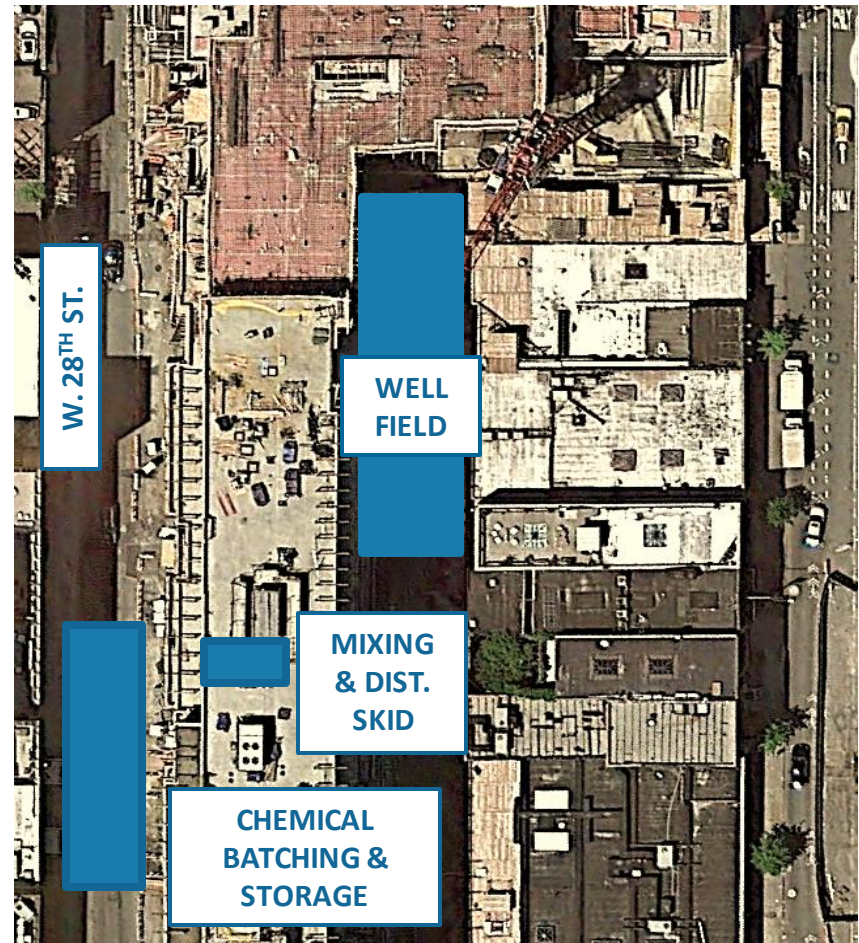
FIELD APPLICATION

Field Application Design

- Designed based on multiple applications with emphasis on achieving remedial goals in single application.
- Injection wells installed to be accessible upon completion.
- Design called for 100,000 to 180,000 lbs of persulfate.
 - 72,700 lbs in first application
 - 60,300 lbs of 50% sodium hydroxide
 - Approximately 35,000 gallons of reagent solution (250 g/L persulfate)
- Design incorporated the RemMetrik process utilizing Wavefront technology.

Field Application Logistics

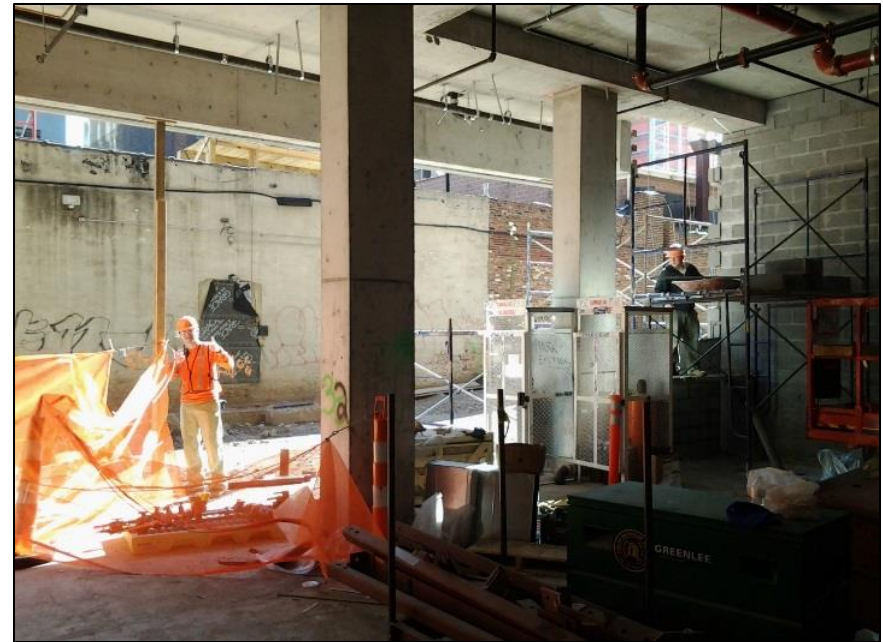
- Difficult spatial constraints from construction activities
- Temporarily closed lane of W. 28th St. each day for batching. Road was open during injection.
- Over 400 daily construction personnel
- Total access window of 9 days.



Batching



Mixing and Distribution Areas

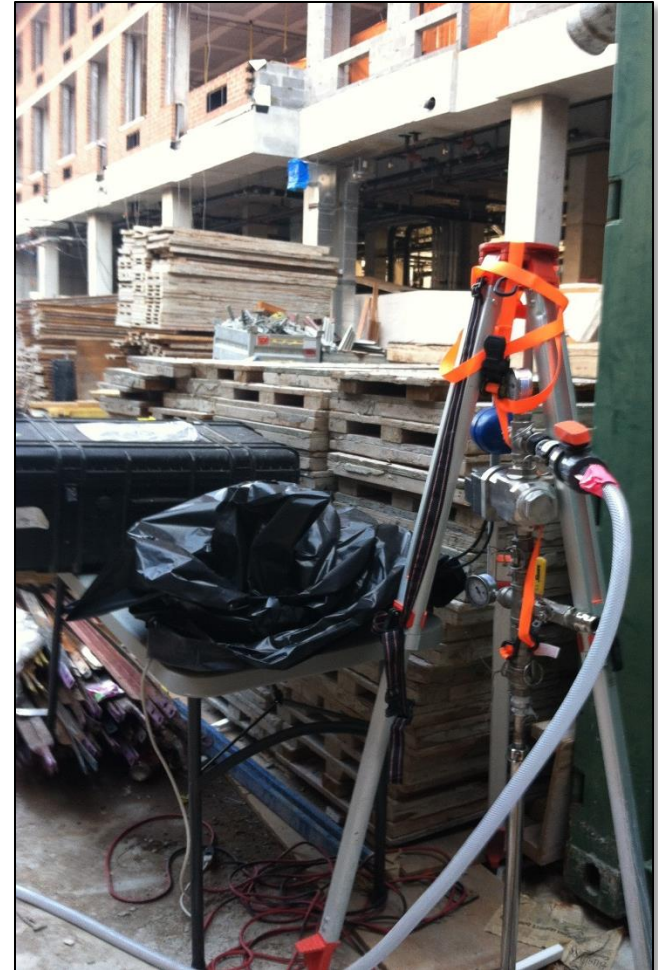


Well Field



Field Application

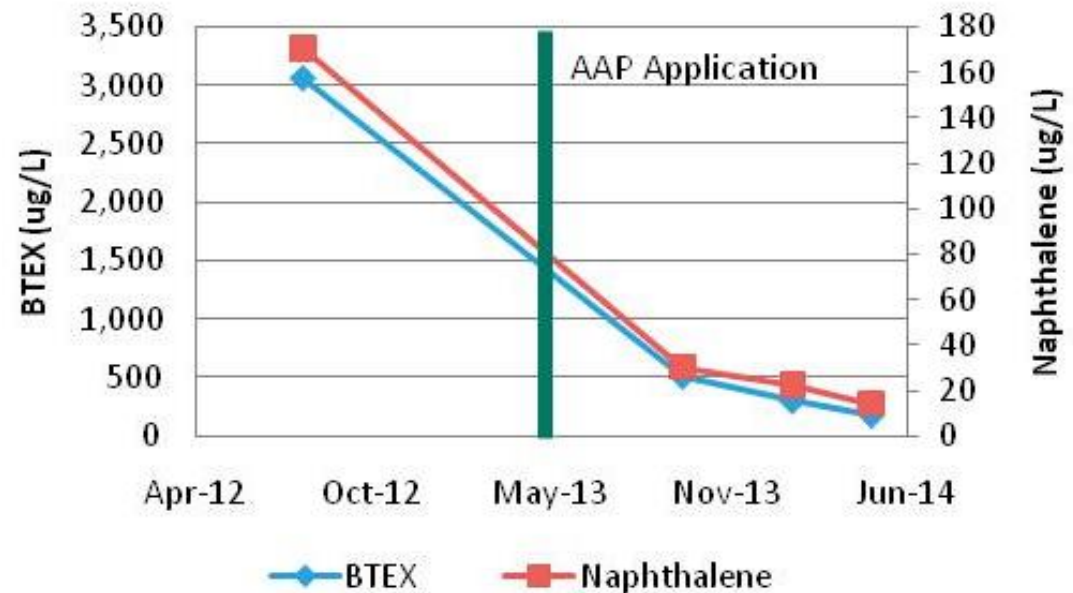
- Occurred May 7 to 17, 2013
- Performed by XDD in cooperation with ZEBRA Environmental and Fleming-Lee Shue.
- 72,372 lbs of alkaline activated Klozur persulfate injected in 35,432 gallons of solution.
- Completed on schedule and within budget, with no impact to construction activities.



Groundwater Results

- Monitoring conducted approximately 5 months after the application in three quarterly events.
- BTEX and naphthalene GW concentrations decreased by 92 to 95%.

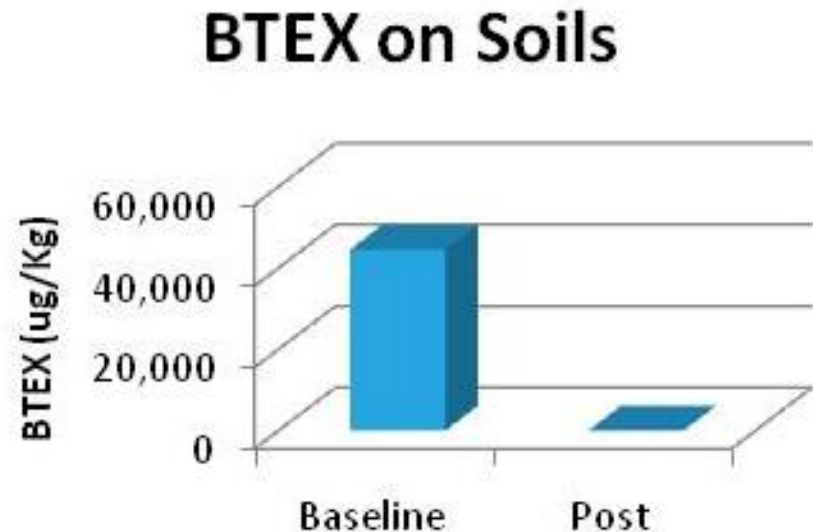
**Rebound was
Not Observed**



Soil Results

- Soil sampled approximately 5 months after the application.
- BTEX concentrations reduced by 99.9%.

**DRO/GRO Soil
Concentrations were
reduced by an
Average of 99.2
percent**



Conclusions

- Single application of alkaline activated persulfate effectively treated BTEX, DRO and GRO
 - Up to 4,000 mg/Kg DRO and GRO
- No rebound observed after 3 quarterly monitoring events.
- Site closed by NY-DEC

Questions



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Environmental Management & Consulting

RemMetrik, LLC

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Do it right. Do it once.