Cadmium and VOC Bioremediation in the Richmond Zeneca Site

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Introduction

Background Information about Cadmium

- Cd has gotten worldwide attention for its large accumulation in agricultural soils and its anthropogenic activities.
- Cadmium contamination in soil is a global issue, and has many negative side effects on our agricultural yields, oceanic toxicity, and human health

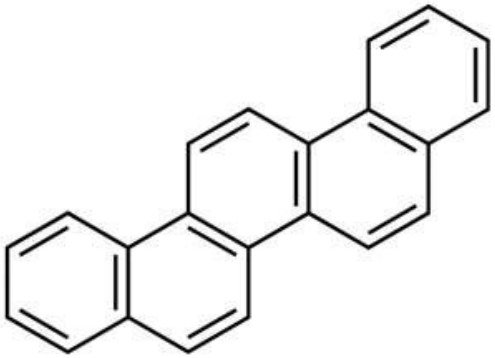
(Richmond Progressive Alliance, 2021)

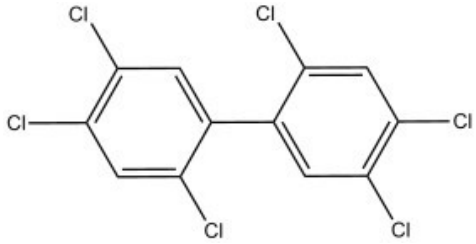
Zeneca Site: Location

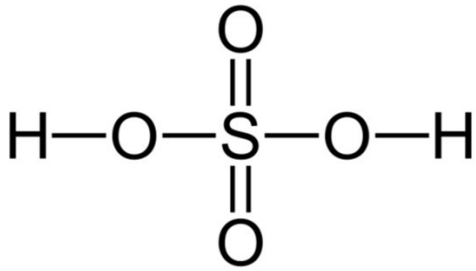
- Heavily contaminated site
- Richmond Shoreline
- Potential for housing use,
  - But lacks environmental safety.

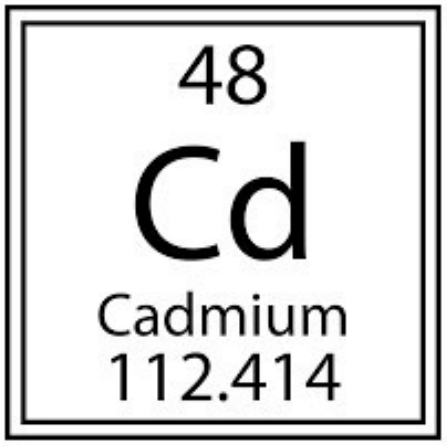
Richmond Zeneca Site

- Manufacturing site for:
  - Sulfuric Acid
  - Pesticides
  - Fungicides
- Found in Soil:
  - Heavy metals (Cadmium compounds amongst many others)
  - Pesticides
  - Sulfuric Acid
  - VOCs
  - PCBs, PAHs (harmful aromatics)









Current Efforts at Zeneca Site

- REMOVAL OF CONTAMINATED SOILS
- SEDIMENT CAP REPLACEMENT
- POST REMEDIAL GROUNDWATER, SURFACE WATER, AND STORMWATER MONITORING
- POST REMEDIAL AIR MONITORING

(Richmond Side, 2024)

Who Could Be Affected?

- Current nearby residents
- Possible homeless populations near the Zeneca site
- Future homeowners
- Surrounding shoreline wildlife
- Nearby Community Workers

Testimony from Community Member

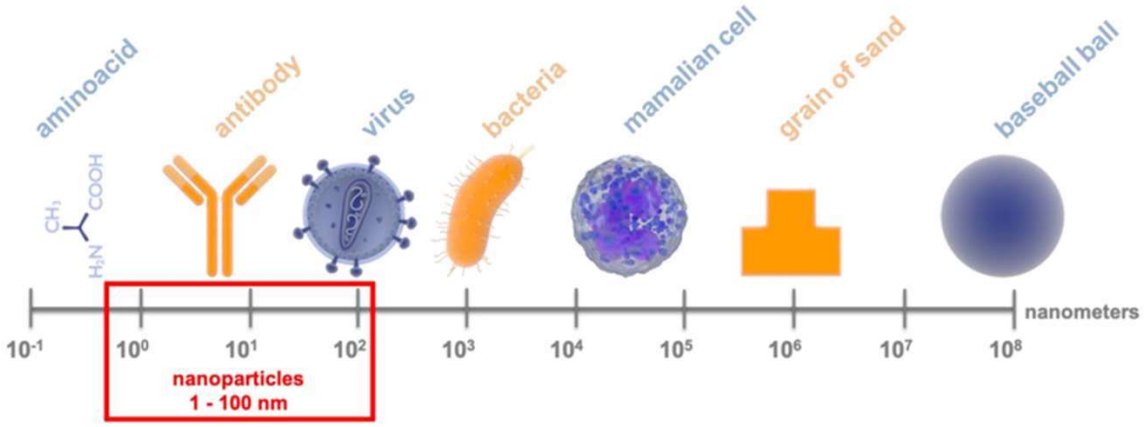
"An unusual number of tumors, cancers and illnesses surfaced among 24 individuals out of 300 working full time in the neighborhood within a two year period. Of the 24 individuals, 11 are dead. Maybe some of those could be considered normal. I do not consider my case normal [...] I missed three days of work for illness in more than 25 years of professional work. A silent, insidious and deadly toxic exposure altered and damaged my genetic code, allowing these tumors to grow unfettered."

-Sherry B. Padgett< Berkeley Daily Planet, 11-9-2004

Health Inequities At Play

- Built Environment
- Lifestyle (for some)
- Healthcare Access for affected residents and victims

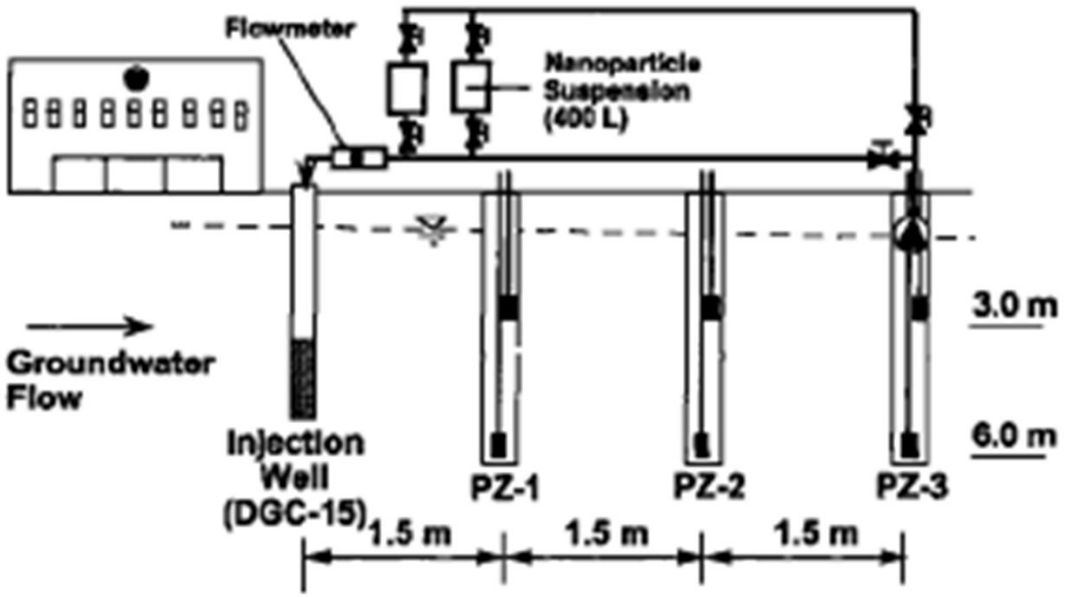
Possible Solution(s): Nanoparticles



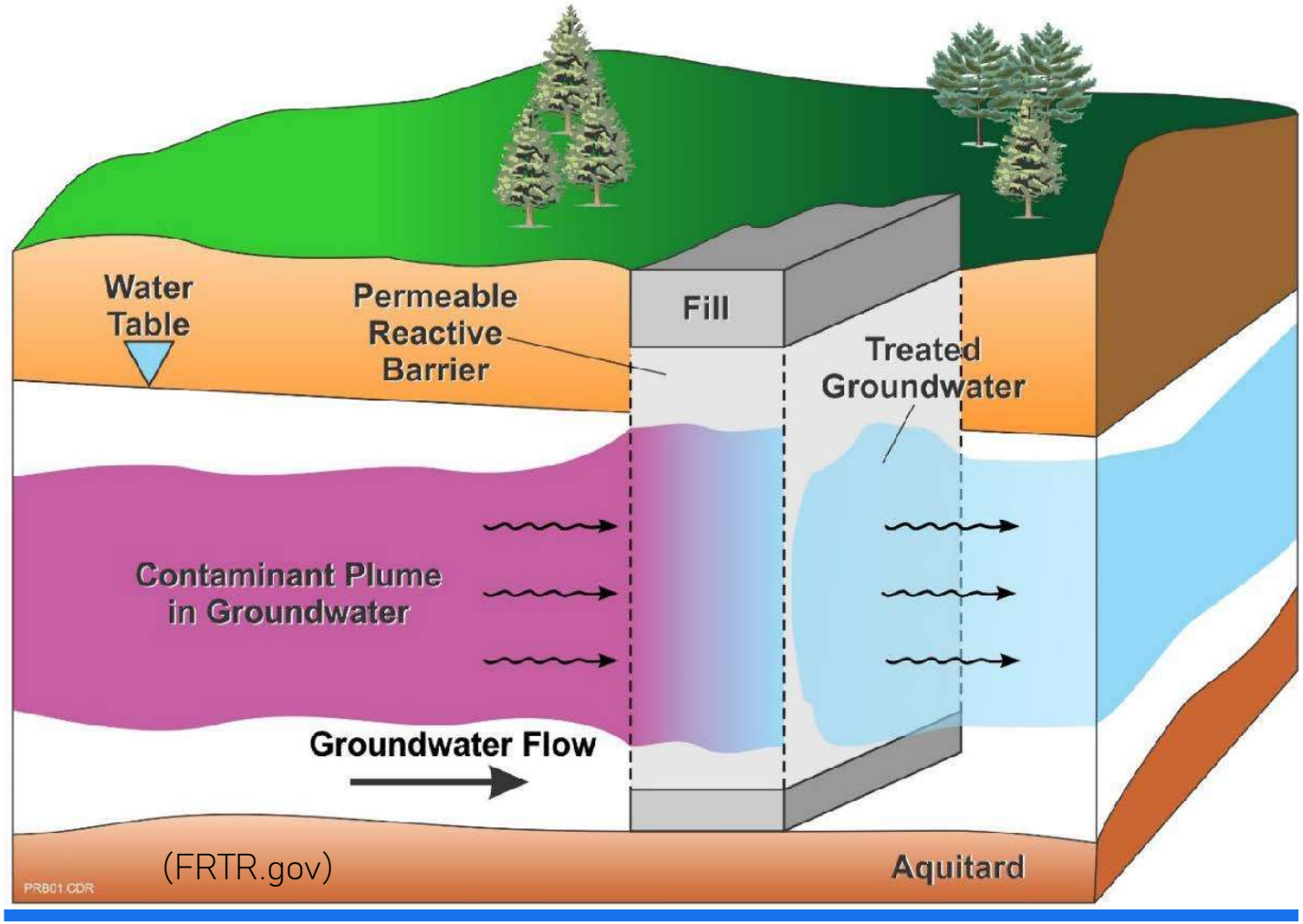
(Steckiewicz, et al. 2020)

- Range between 1 and 100 nanometers
- Size of a nanoparticle impacts its properties
  - Example: Quantum Dots' light emission is proportionate to the size it is.

Zero Valence Iron Permeable Reactive Barriers



(Galdames. et al. 2020)



(FRTR.gov)

Permeable Reactive Barriers

- Used for treating groundwater
- In situ soil treatment is very promising as it requires little alteration of soil structure and integrity.
- BUT presents issues with lower remediation potential because of varying contaminant levels.
  - Zero Valence Iron (ZVI) is implemented to these systems to amend these issues.

Review

Zero-Valent Iron Nanoparticles for Soil and Groundwater Remediation

Alazne Galdames [1], Leire Ruiz-Rubio [1,2,*], Maider Orueta [3], Miguel Sánchez-Arzalluz [3] and José Luis Vilas-Vilela [1,2]

- Inert state of Iron (Fe0)
- Modular in how it can be applied (naturally polymerized NZVI)
- Inexpensive, nontoxic, moderate reducing agent.
- When paired with water, can form hydrogen peroxide, which then gets reduced back to water.
  - This property allows it to be a strong oxidative capability to degrade organic contaminants and metals

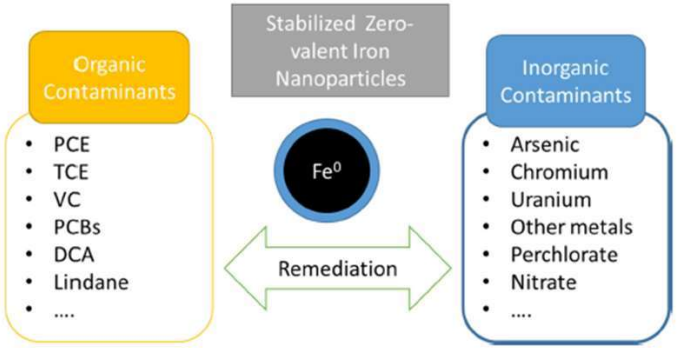


Figure 7. Summary of the main contaminants remediated with stabilized NZVI.

$$Fe^0 + O_2 + 2H^+ \rightarrow Fe^{2+} + H_2O_2$$

$$Fe^0 + H_2O_2 + 2H^+ \rightarrow Fe^{2+} + 2H_2O$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \cdot OH + OH^-$$

NZVI in PRB Technology

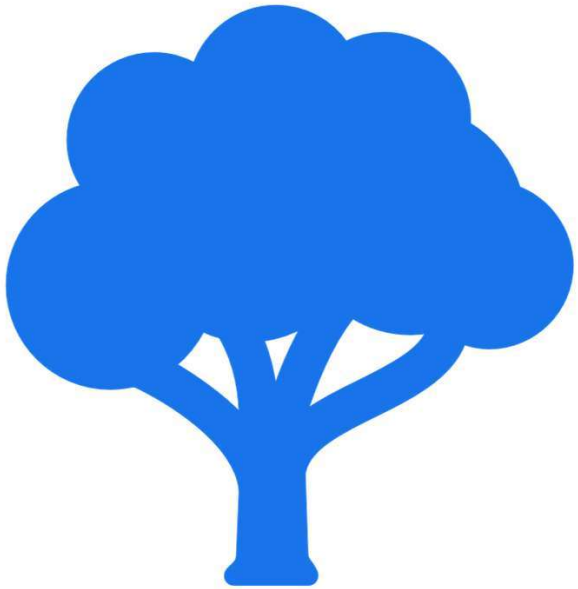
Table 6. Summary of pilot and full-scale tests for polymer coated NZVI particles.

Pollutants	Conc. Decrease	Addition Method	Site	Comments	Location	Reference
Chlorinated compounds	>90%	Injection in two phases		30 days	Hamilton Township, New Jersey (USA)	[32]
TCA, DCE, TCE, PCE	80–90%	n/a	Soil	n/a	Naval Air Engineering Station of Lakehurst (USA)	[98]
TCA, DCE, TCE, PCE	80–90%	n/a	Soil	n/a	Naval Air Station of Jacksonville (USA)	[98]
PCE	90%	n/a	Soil	2 years after, more reduction	Bornheim, Germany (Europe)	[137]
PCE, TCE, DCE	60–75% for Horice and 90% for Pisecna	Injection (82 injection wells)	Soil	n/a	Czech Republic (Horice and Pisecna)	[137]
Chlorinated compounds	>90%	n/a	n/a	30 days	Hamilton Township, New Jersey (USA)	[32]

"Some pilot and full-scale tests have carried out by using stabilized NZVI (Table 6). In Hamilton Township, New Jersey (USA), a remediation strategy based on this nanotechnology showed positive results. The NZVI were injected in two phases and the duration of the test was 30 days. The results showed a decrease in the concentration of chlorinated contaminants of up to 90 percent"

(Galdames et al. 2020)

Limitations



- Formation of nanoparticle aggregation
- Lack of mobility of bare NVZI
  - Where polymer coating comes in
- More analysis on potential ecological and environmental risk because of their nanoparticle scale
- Lack of studies on the ecotoxicity or bioaccumulation on pilot and complete clean up.

Conclusion

- NZVI's can be a promising solution to the Richmond Zeneca site
- Provides a wide ranged list of targeted contaminants, (metals, VOCs, PCBs, etc.)
- Has a high concentration % decrease in contaminants,
- Has versatile colloidal properties that can allow them to improve when treated with biodegradable polymers

Questions?

Works Cited

- Galdames, A., Ruiz-Rubio, L., Orueta, M., Sánchez-Arzalluz, M., & Vilas-Vilela, J. L. (2020, August 11). *Zero-valent iron nanoparticles for soil and groundwater remediation*. International journal of environmental research and public health. https://pmc.ncbi.nlm.nih.gov/articles/PMC7460444/
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