"CAN LOW TEMPERATURE THERMAL DESORPTION BE CONVERTED TO DESTRUCTION AND BE MORE SUSTAINABLE THAN TRADITIONAL INCINERATION?"

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KRÜGER VEOLIA

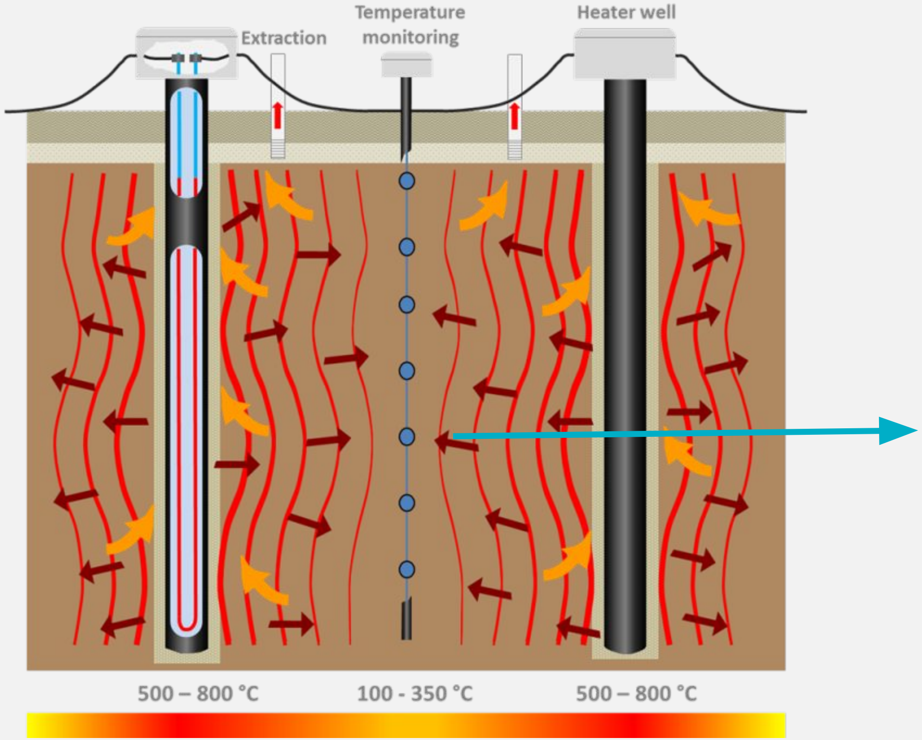
A matter of clean soil

TRADITIONAL THERMAL REMEDIATION
WHAT IS IT?

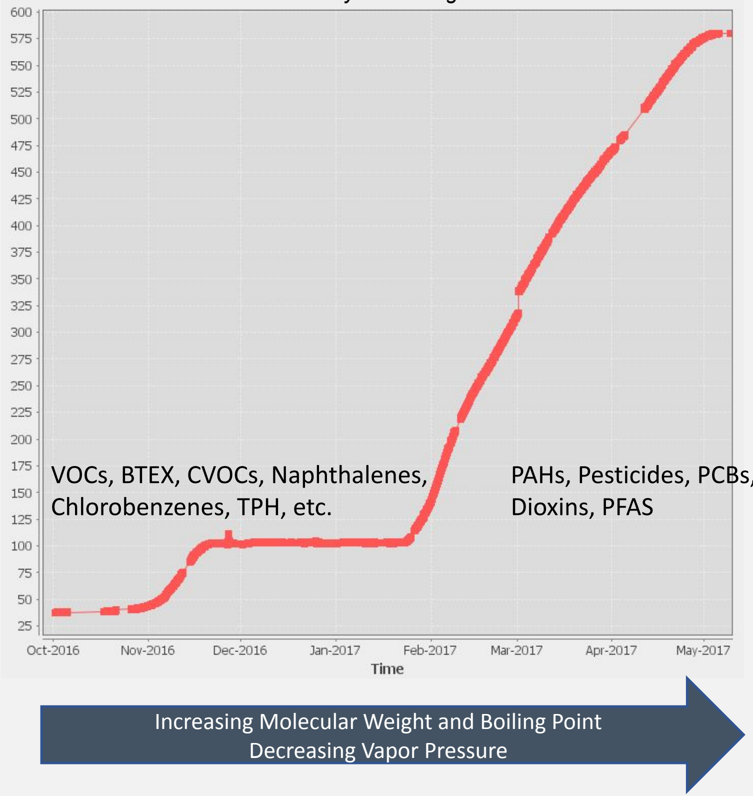
- Source zone technology
- Employs heat to volatilize organic chemicals
- Chemical and water vapors are:
  - Captured by vacuum
  - Brought to the surface
  - Treated before discharge

Separate CoCs from soil

THERMAL CONDUCTIVE HEATING (TCH)
OPERATING TEMPERATURES



Ref/ Vietnam - TCH by TT & Krüger Soil Remediation



THERMAL REMEDIATION
DO WE REALLY WANT TO EXTRACT THE COCs?

Traditional approach: Heat fast and get it out!

We have references on Dioxin, PCB, PCP, PFAS, Mercury, Parathion, Lindane and many others

But is it attractive to extract all the contaminants?
- Highly toxic compounds
- Solid at condenser temperature compounds
- Flammable or reactive compounds

Can longer residence time lead to destruction of contaminants?

Substantially lower energy costs compared to high temperature incineration of soil (80-88% reduction)

Examples

- Mixed (Mercury, pesticides, sulphur)
- Dioxin
- PFAS

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MIXED CONTAMINATION
PARATHION, MERCURY SULFIDE AND EXCESS SULFUR

Chemical reaction is required to address mercury sulfide

- $HgS + O_2 \Rightarrow HgO + SO_2$
- $HgO \Rightarrow Hg + ½O_2$

Parathion

- Highly toxic - TWA 0.05 mg/m^3
- Thermally unstable
- Flammable decomposition product

Sulfur

- Flammable vapors
  - Solid at treatment plant temperature - may block pipes
  - Not a remediation target, but will prevent evaporation of mercury

MIXED CONTAMINATION
PILOT SCALE APPROACH

Destroy parathion, oxidize sulfur and mercury sulfide, decompose mercury oxide
Activated carbon filtration, Sulfur impregnated for vapor phase
Target temperature 350 °C

Slow controlled heating to slowly evaporate/decompose parathion at 80-110 °C
Superheating extraction stream to decompose extracted vapors
Monitoring LEL

In soil oxidation of sulfur at 220-250 °C - neutralisation of sulfur dioxide in alkaline scrubber

Ventilation at 250-350 °C to oxidize mercury sulfide
Decomposition of mercury oxide at 350 °C

Test conducted in sealed steel box with nitrogen blanket option

MIXED CONTAMINATION
PILOT SCALE RESULTS

99.98% destruction of parathion
Soil concentration of all organic contaminants (mainly paranitrophenol from parathion decomposition) below detection level at 200 °C soil temperature.

Mercury remained above 3 mg/kg at 350 °C
Mercury soil concentrations below 2 mg/kg at the end of treatment at 500 °C

Considerable HSE improvement by managing 10 g of parathion in the treatment plant rather than 50 kg

Considerable operational improvement by managing SO_X rather than elemental sulfur

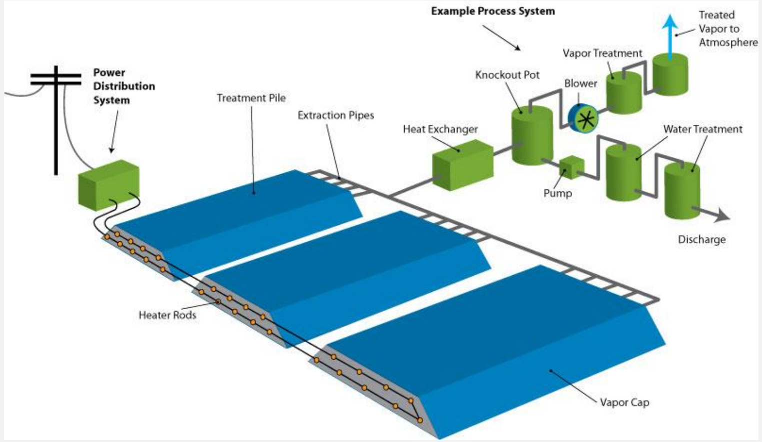
LEL proved manageable by controlling heating rate and ventilation

AGENT ORANGE SPILL
DIOXINS, PHENOXY HERBICIDES AND JET FUEL

Dioxins
- Highly toxic
- Persistent
  - Reason for remediating the soil

Lower priority contaminants
  - Phenoxy herbicides, primarily 2,4,5-T and 2,4-D
- Jet fuel and other volatile and semi volatile contaminants

AGENT ORANGE SPILL
LARGE SCALE APPROACH



Heating strategy

- Separation by evaporation from the soil
- Heat up as fast as practically and economically advantageous
- Target treatment temperature 335 °C
- 3 weeks at temperature

Liquids and vapor treatment plant

- Condensation, macro-porous polymer extraction and activated carbon

Two phases 45000 m^2 each

AGENT ORANGE SPILL
LARGE SCALE RESULTS

Dioxins in soil remediated to 9 ppt TEQ in phase one
Dioxins in soil remediated to 0.2 ppt TEQ in phase two

Other organic contaminants were removed below detection limits

Slower heating stage one achieved 90-97% dioxin destruction
Faster heating stage two achieved 60-75% dioxin destruction

Other organic contaminants contributed to activated carbon consumption

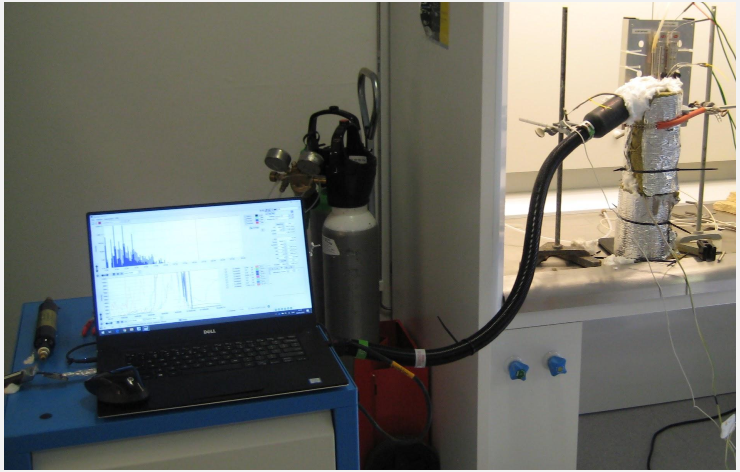
PFAS
LAB SCALE TEST OF SOILS FROM FIRE TRAINING GROUNDS

Round one feasibility testing: Heat and ventilate
Target treatment temperature 250 - 500 °C

PFAS total below 1 ug/kg (400 °C for 2 weeks)
Only PFOS and PFHxS are detected in treated soil

Some precursors are recovered in high yield

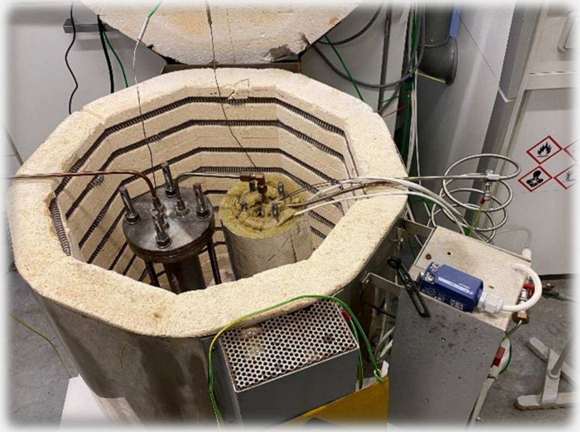
All long chain PFAS are decomposed



Online mass spectrometry confirm perfluorinated aliphatic compounds

No commercial analysis is available for perfluorinated aliphatic compounds

PFAS
LAB SCALE TEST OF PFOS SPIKED SAND



Round two optimization of mineralization

Slow heating - minimal ventilation

600 °C decomposition reactor - 3 different catalysts

25% soluble inorganic fluoride (sand artificial soil and alkaline scrubber)
75% insoluble fluorine (XPS suggest inorganic minerals)
0.05% PFOS found in scrubber and soil
Mass balance adds up - all fluorine accounted for

DOING CHEMISTRY DURING THERMAL REMEDIATION
CONCLUSION

By observing contaminant thermal stability and balancing evaporation and decomposition it is possible to conduct controlled high efficiency degradation during thermal remediation

Degradation can improve health and safety

Chemical conversion can enable remediation of non volatile contaminants

Mineralization will reduce activated carbon usage

Fast extraction is not necessarily optimal

A heated extraction system can contribute to degrading extracted vapors

DOING CHEMISTRY DURING THERMAL REMEDIATION
OUTLOOK

In soil mineralization can minimize usage of sorbents as well as the need for waste handling

The energy consumption of a 350 °C high temperature thermal remediation is ⅛ to ⅕ of high temperature incineration while the soil can be treated on site

A few words of caution:

- Keep an eye for degradation products and make sure to monitor them
- Consider mass balance check to account for all of the contaminant mass
- Make sure that no contaminants worse than the original ones are formed

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THANK YOU

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Please, feel free to reach out to us here at the conference for more details.

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