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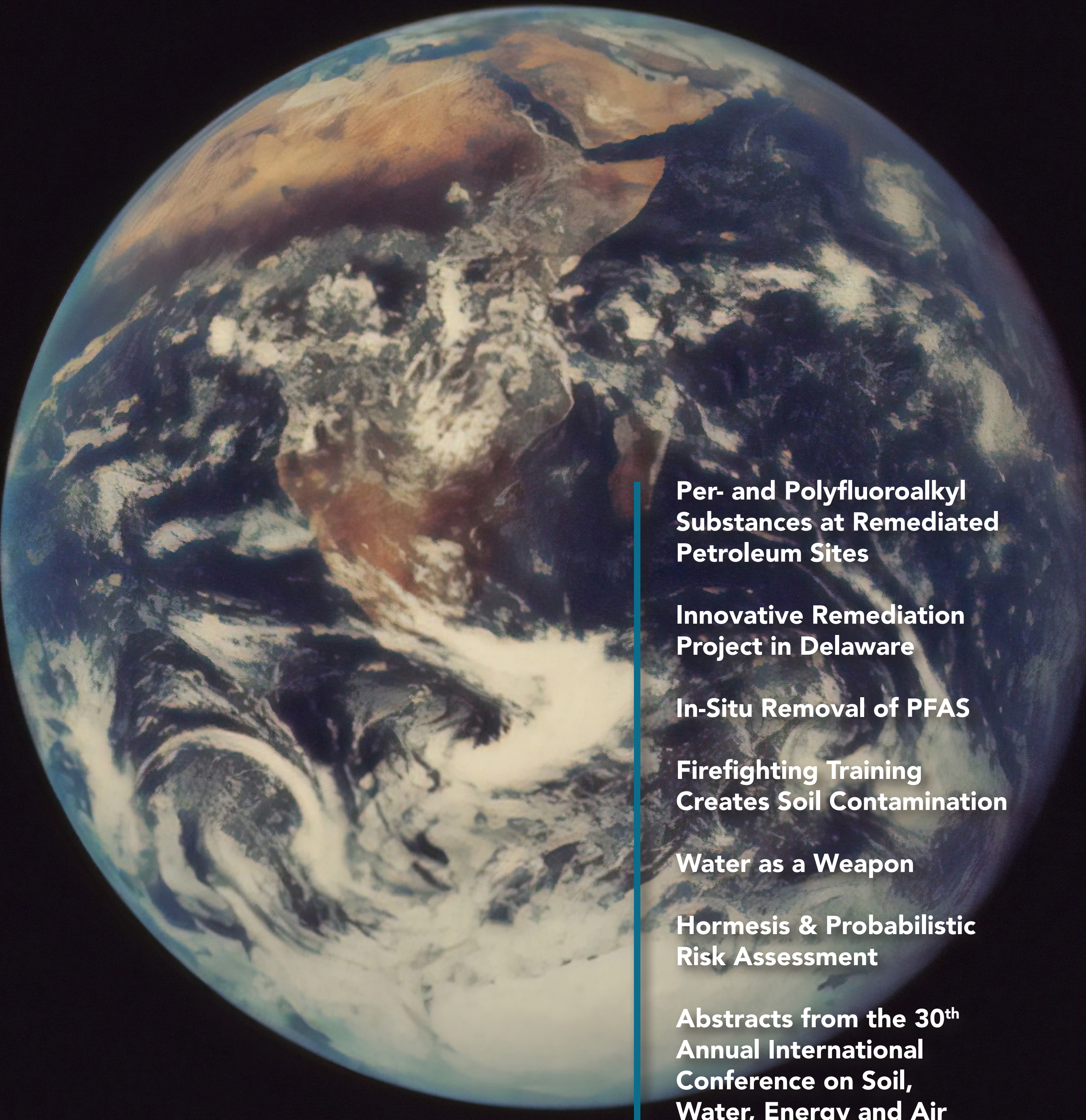

Per- and Polyfluoroalkyl Substances at Remediated Petroleum Sites

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Abstracts from the 30th Annual International Conference on Soil, Water, Energy and Air

Firefighting Training Creates Soil Contamination

After years of ongoing use of aqueous film forming foam (AFFF), a fire training center located in the United Kingdom showed high levels of PFAS (Per- and Polyfluoroalkyl Substances) contamination. Faced with a potentially expensive cleanup, the remediation team devised a treatment strategy to immobilize the harmful chemicals through in-situ stabilization and solidification using CETCO FLUORO-SORB® 100 adsorbent.

PFAS CHEMICALS AND THEIR IMPACT

In recent years, PFAS substances (man-made chemicals that includes PFOA, PFOS, PFBS, GenX, and many other derivations) have become recognized as Contaminants of Emerging Concern. Attention to this issue has grown enough that in the United States, the EPA has begun the regulatory development process for listing these chemicals as a hazardous substance.

For over six decades, PFAS have been key components in common products used worldwide such as non-stick cookware, waterproof fabrics and clothing, stain-resistant carpeting, food wrappers, make-up, paints, firefighting foams, and numerous products designed to resist grease, water, and oil. Over time, these commonplace chemicals have been found to have seeped into the food chain and water supply—a significant concern, as scientific study has determined PFAS exposure can lead to negative health impacts on both animal and human populations.

In addition to their health risks, the strong carbon-fluorine chemical bonds of PFAS, which is what provides their useful properties, make them highly environmentally stable. As a result, PFAS remain intact in the environment—they do not readily break down over time—lending them the nickname "forever chemicals." This persistence can lead to accumulation, increasing contamination levels while posing remediation challenges for contaminated groundwater, surface water, and wastewater—and in particular, contaminated soil and sediment, which are frequently the source of water contamination.

A CONTAMINATED SITE

The UK-based fire training center is a prime example of a PFAS contamination problem and the challenges its remediation presents. Years of firefighting training at the site had left it substantially contaminated—PFAS chemicals are key ingredients in the aqueous film forming foam (AFFF) firefighters use to extinguish fires involving flammable and combustible liquids. Because of PFAS's stability to the point of near indestructibility, when applied, these chemicals form a thermal and evaporation barrier that extinguishes combustion, making them highly effective in dousing flames under conditions where water is ineffective. Facilities all over the world provide AFFF training instruction to firefighters to help them develop proficiency in the use and application of these firefighting foams. This typically includes hands-on exercises, and the repeated use of AFFF in regular training results in a build-up of PFAS contamination at training sites.

This center was no different, and as part of the firefighting training conducted regularly at the facility, these PFAS-laden foams had been used consistently for years.

As a result, groundwater and near-surface soils at the site had PFAS contamination levels of long-chain compounds, PFOS and PFOA exceeding 100 ppb (parts per billion— research suggests PFAS concentrations above 1.4 ppb may cause groundwater contamination). Also, because the fire training facility had been used for practice with gasoline and diesel fires, the PFAS contamination was compounded with a co-contamination of significant TPH (total petroleum hydrocarbons).

Further, because the site was situated near a tidal marine estuary, additional concerns included poor geotechnical ground conditions due to marine silts and groundwater tidal influences, as well as the presence of high sulfates.

THE CHALLENGES FOR REMEDIATION

This contamination profile created a set of challenges for PFAS remediation. The presence of gasoline/diesel

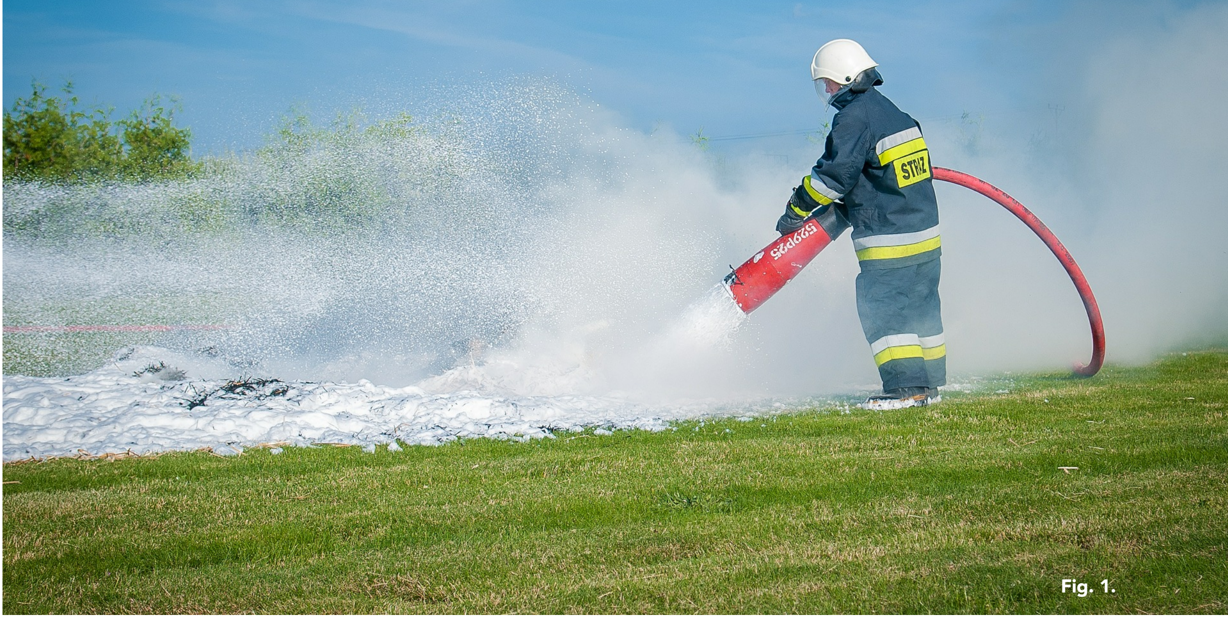

Fig. 1.

contaminants can affect the efficiency of certain remediation products, with the presence of seawater complicating circumstances further, as saltwater can adversely affect the removal efficiency of ionic exchange resins (IER) that might otherwise be employed to remediate PFAS contamination.

A SOLUTION FOR PFAS CONTAMINATION

The remediation team's plan for the training facility was to devise a remediation strategy that maximized reduction of the PFAS contaminants and was also cost conscious—the public sector training facility had a very limited budget for a contamination solution.

Beginning with solidification/stabilization treatability trials, the team tested various approaches using separate 64-day leach tank tests based on EA NEN7375:2004/US EPA 1315. Once the results were analyzed, the team was able to confirm that the levels of PFAS and TPH in the soil would prevent the use of granular activated carbon (GAC)—adsorption by GAC would be fouled by the co-contaminants found in the samples.

CETCO and ATG Group commissioned a laboratory study of PFAS contaminated soil treated with FLUORO-SORB® 100 adsorbent media and cement. Samples of an untreated soil, TTP1, were obtained. The soil was a brown loam with clay and gravel. TTP1 was tested for total petroleum hydrocarbons (TPH) and two PFAS compounds, PFOA and PFOS.

Test results for untreated TTP1 were:

Aliphatic TPH = 1100 mg/kg

Aromatic TPH = 610 mg/kg

PFOS = 1.5 mg/kg

PFOA < 0.1 mg/kg

Because the PFOS concentration was lower than expected, the TTP1 sample was spiked with 100 mg/kg of PFOS (heretofore referred to as TTP1-S). Thus, the total PFOS concentration in the spiked soil sample, TTP1-S, was 101.5 mg/kg. Spiked soil specimens were then treated with 2% by weight cement and 0.5-4% by weight FLUORO-SORB™ 100. Six 500g monoliths were formed and separate 64-day tank tests conducted on each per EA NEN 7375:2004/US EPA 1315. In the US EPA 1315 tank test, each treated soil monolith was placed in a water bath and then removed after periods of 6-hr, 24-hr, 2.25 days, 4 days, 9 days, 16 days, 36 days and 64 days. The water bath was then analyzed for contaminants that have leached out of the treated soil monolith and into the water. The water bath was replaced to start the next time period and the process was repeated.

Test results of leach water of TTP1-S treated with 2% cement and 0.5% FLURO-SORB® 100 adsorbent after 6-hr, 24-hr and 2.25 days were all:

Aliphatic TPH <1.0 ug/l (below detection limit)

Aromatic TPH <1.0 ug/l (below detection limit)

PFOA <50 ppt (below detection limit)

PFOS <50 ppt (below detection limit)

Tank tests for the higher adsorbent media loadings, up to 4% FLUORO-SORB® 100 adsorbent, were also below detection limits; therefore, FLUORO-SORB® 100 adsorbent did not show any signs that overdosing was detrimental.

In summary, the test results showed that FLUORO-SORB® 100 adsorbent is an effective additive for in-situ solidification stabilization of PFAS contaminated soil, even when the soil has TPH co-contaminants. Granular activated carbon (GAC) can be fouled by TPH and reduce its PFAS adsorption effectiveness. Thus, there may be an advantage to using FLUORO-SORB® 100 adsorbent instead of GAC as an additive in PFAS in-situ solidification stabilization applications.

With IER and GAC determined to be less effective due to the known co-contaminants, the team selected CETCO FLUORO-SORB® adsorbent as the most effective sorbent additive to use in their remediation plan. An NSF-certified treatment media, FLUORO-SORB® adsorbent handles PFAS effectively and economically, specifically targeting and adsorbing PFAS in groundwater and soil. It was found to be particularly appropriate for use at the fire training site, as it treats the full spectrum of PFAS without being affected by co-contaminants such as diesel, BTEX, TCE, hydrocarbons, 1.4 dioxane, natural organic matter, diesel, and saltwater.

REMOVAL AND REMEDIATION PLAN

PFAS remediation using CETCO FLUORO-SORB® adsorbent, can take any of several forms:

- As a flow-through filtration media for drinking and groundwater
- As a component in sediment capping within a CETCO REACTIVE CORE MAT® composite geotextile mat
- As part of an In Situ Stabilization and Solidification (ISS) solution to immobilize the PFAS at the contamination site
- As a Permeable Reactive Barrier between contaminated area and downstream water sources to filter water of contaminants as they move though the permeable barrier

With their findings and understanding of the specific circumstances of the fire training site, including the soil type and level of contamination (which determines the size of sorbent particles required) and the type of groundwater present (which indicates both how much the contamination may be carried by groundwater movement), the team selected a solution that included excavating and disposing impacted soil and treating near-surface soil through ISS, utilizing cementitious binders and FLUORO-SORB® 100 adsorbent.

Methods for ISS include permeation grouting, soil mixing, and jet grouting, each with its own particular

Fig. 2.

advantages and applicability, depending again on the specifics of the site.

- Permeation grouting is the least destructive method, involving the drilling of small holes and injecting a slurry mixture (typically FLUORO-SORB® and concrete) to permeate the ground at targeted depths. This method is effective for mass treatment and containment, and is safe to use in proximity to buildings and other structures.
- Soil mixing involves mechanical rotary mixing of the contaminated soil, either dry or wet. Because of the sizable machinery required, this method cannot be used in proximity to structures and requires substantial overhead space.
- Jet grouting-requires highly specialized equipment to inject the slurry mixture at high pressure and mix it with the soil at targeted depths. Also good near structures, jet grouting equipment requires minimal headroom and can be used even in the basement of a building. This method is good for mass treatment with minimal disruption to the soil.

PFAS REMEDIATION SUCCESS TO SAFEGUARD THE COMMUNITY

As a result of the remediation team's research and careful evaluation, a plan has been presented to address the PFAS contamination taking into consideration the unique circumstances of the fire training center.

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