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Chapter 8

REMEDIATION OF A FORMER MGP SITE IN NORWICH NEW YORK: A CASE STUDY

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ABSTRACT

Former Manufactured Gas Plant (MGP) production from circa 1860s through the 1950s at a site in Norwich, New York, resulted in impacts to both on-site and off-site soils and groundwater. Site remediation includes four phases of treatment: in situ solidification (ISS) of on-site source materials; recovery of NAPL from off-site; in-situ chemical oxidation (ISCO) of off-site areas; and enhanced bioremediation of off-site groundwater.

Approximately 52,103 cubic yards (39,835 cubic meters) of impacted sand and gravel were solidified in-situ using auger mixing technology, and over 54,000 gallons (210,000 liters) of NAPL have been recovered to date. An ISCO bench-scale study revealed that four applications of hydrogen peroxide will reduce BTEX and naphthalene by 99% and TPH by 50%. Full-scale ISCO application will occur upon completion of NAPL recovery, followed by enhanced bioremediation of dissolved phase contamination (benzene and naphthalene).

1. INTRODUCTION

A Manufactured Gas Plant (MGP) is a facility that produced gas for lighting and heating homes and businesses. The Norwich former MGP, Norwich, Chenango County, New York, USA, produced gas using the coal gasification and carbureted water gas processes. Coal gas was produced by heating coal in retorts or beehive ovens, carbonizing the coal in the absence of air. The carbureted water gas process involved the passage of steam through burning coal, forming a gaseous mixture (water gas or blue gas) that was sprayed with oil as it then passed through a super heater. The oil spray would generate additional gas, enhancing the heat and light capacity of the overall gas mixture.

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In each process, the gas was cooled and purified prior to distribution. During cooling, an oily liquid known as coal tar would condense from the hot gas and settle in the bottom of gas holders, pipes and other structures. These structures were typically built below ground, using groundwater as a bottom seal. Therefore, they posed significant potential to introduce coal gas byproducts directly into the ground. The gas was purified using wood chips treated with iron oxide to remove hydrogen sulfide from the gas.

Coal tar is typically a reddish-brown oily liquid, which does not readily dissolve in water. It is commonly categorized as a non-aqueous phase liquid (NAPL). Although most coal tars are slightly denser than water, the difference is slight. Consequently, the coal tar can either float or sink when in contact with water. The coal tar is evident as sheen on a water surface or as NAPL in soil or water. At the Norwich MGP site, coal tar was found in the subsurface surrounding former MGP structures, and in downgradient areas.

The Norwich former MPG site is located in a residential and commercial area. The former MGP operations previously occupied approximately 1 acre (0.4 ha). It is believed that plant operations began sometime between 1863 and 1887. Gas production ceased in 1953. Little is known of the generation and disposal practices of the residues from the Norwich MGP, except that two subsurface tar storage vessels existed until they were removed in 1997 as part of an Interim Remedial Measure (IRM). The IRM also included removal of a relief holder, related piping, and surrounding soil.

Specific volatile organic compounds (VOCs) of concern include benzene, toluene, ethylbenzene, and xylenes (collectively, BTEX). Semivolatile organic compounds (SVOCs) of concern are polycyclic aromatic hydrocarbons (PAHs).

2. RECORD OF DECISION

The presence of hazardous wastes at the Norwich site, including MGP tars and purifier waste (i.e., spent wood chips), created significant threats to human health and the environment. To eliminate or mitigate these threats, the New York State Department of Environmental Conservation (NYSDEC) selected a remedy with these components:

- In-situ solidification (ISS) of impacted on-site source area
- Removal of free-phase NAPL from select off-site areas
- In-situ chemical oxidation (ISCO) treatment of off-site source material
- Bioremediation of dissolved phase contamination

Performance goals for ISS treatment included:

- Unconfined compressive strength (UCS) greater than 50 pounds per square inch (psi) (345 kPa) at 28 days
- Hydraulic conductivity less than 1×10^{-6} cm/s at 28 days

Note that solidification refers to the process of encapsulating a waste to form a solid material and to restrict contaminant migration by decreasing the surface area exposed to leaching (USEPA, 2010). As such, the focus should be to divert groundwater flow around the low-permeability monolith to minimize contaminant leaching. The strength criterion should be secondary (in the authors' opinion.)

The ISS phase of the remediation was completed spring of 2011. Off-site NAPL recovery operations began in 2009 and are ongoing. ISCO treatment is in the planning stages, and will be implemented when the rate of NAPL recovery tapers off.

In general, the local community is supportive of the selected remedy, particularly the creation of developable property.

3. SITE GEOLOGY AND HYDROGEOLOGY

The site is underlain by four stratigraphic units, in order of increasing depth:

- Fill: Loose to compact sand and gravel with concrete fragments, coal, and asphalt, extending to depths up to 7 ft (2 m).
- Sand and Silt: Loose to medium compact fine sand and silt, generally extending to depths of about 5 ft (1.5 m). (It is absent in areas where fill is deep). This stratum is interpreted to be alluvium.
- Gravel: Loose to medium compact gravel and sand, extending to depths of 17 to 22 ft (5 to 7 m). This stratum is interpreted to be glacial outwash.
- Clay: Medium to stiff clay. This stratum serves as a continuous confining layer beneath the Gravel.

Index testing of representative samples indicates that the gravel stratum contains 8 to 26 percent fines passing the No. 200 sieve size. The fines content in this stratum tended to decrease with depth, being least at the bottom. Atterberg limits tests indicate that the Gravel fines have some plasticity, with Plasticity Indices ranging from 0 to 9 percent.

Geotechnical test borings were made using hollow stem augers and split spoon sampling. Based on consistent Standard Penetration Test blow counts and

the judgment of the driller, it was inferred that the natural soils at this site did not contain significant cobbles and boulders.

Groundwater at the site was typically at a depth of about 6 ft (1.8 m).

4. ISS BENCH STUDIES

ISS bench scale studies were performed by Kemron Environmental Services, Inc., (Kemron), Atlanta, GA. The primary goals of the bench scale treatability studies were to confirm the feasibility of ISS as a remedial remedy at this site and to provide guidance for selection of ISS reagents to achieve required performance criteria in the field. The bench studies focused primarily on reducing the hydraulic conductivity of the gravel soil layer. This was considered key to success of this project. The following reagents were evaluated in the treatability study:

- Portland Cement (PC). This is the primary reagent. PC additions of 5 to 15 percent by weight were evaluated.
- Bentonite (B). Bentonite was intended to reduce hydraulic conductivity. Bentonite additions of 1 to 2 percent were evaluated.
- Cement Kiln Dust (CKD). CKD was evaluated for potential beneficial reduction in hydraulic conductivity, primarily by introducing fines to fill void spaces within the gravel soil. CKD was obtained from the Lafarge Cement Plant, Ravena, NY.

Kemron proportioned the reagents, and then added water to create a slurry. Sufficient water was added to produce a slurry that was visually judged to be pumpable (no slurry testing was performed). The reagent slurry was then mixed with representative soil samples and allowed to cure.

Analytical testing of the soil samples indicated that contaminant concentrations were representative of average or typical conditions. Bench testing was not performed on heavily contaminated soils (which would represent worst case conditions) because it was assumed that heavily contaminated zones within the soil profile would be intermixed and “diluted” during ISS operations. General conclusions derived from the bench studies include:

- As expected, unconfined compressive strength increases with increasing cement content. Addition of CKD typically resulted in only minor strength improvement. Addition of bentonite typically resulted in minor strength reduction.

- Hydraulic conductivity decreases with increasing cement content. Adequate reduction of the hydraulic conductivity of the gravel soil was more difficult to achieve and controlled the design.
- Addition of 1 percent bentonite decreased the hydraulic conductivity of the gravel stratum by about an order of magnitude. Additional bentonite (i.e., > 1%) resulted in negligible further improvement in hydraulic conductivity.
- Addition of CKD resulted in only small decrease in hydraulic conductivity. Reduction was greatest when the cement content was low.

The treatability study indicated that two mix designs: (1) 8% Portland Cement and 1% bentonite or (2) 11% Portland Cement (no bentonite), would meet the stipulated performance criteria, with a predicted hydraulic conductivity on the order of 5×10^{-7} cm/s at 28 days, providing a reasonable safety factor.

5. REMEDIAL DESIGN

Closely spaced test borings were made within the ISS area during final design to establish the elevation of the top of the clay barrier layer across the ISS footprint. These data were used to develop a detailed top of clay surface to define the required depth of ISS treatment at any location. The ISS footprint was subdivided using a 25 by 25 ft (7.6 by 7.6 m) grid, and the required depth of treatment was defined by the deepest clay elevation within each grid box. ISS treatment generally extended 2 ft (0.6 m) into the clay except along the ISS treatment area perimeter, where the toe was increased to 4 ft (1.2 m). The intent was to afford greater certainty that the ISS treatment would extend completely through the impacted soils along the treatment area boundary, providing a continuous cutoff. A smaller toe was considered appropriate within the interior of the treatment area because any minor untreated zones above the clay surface would be isolated and completely confined. Because the design borings were closely spaced and provided reliable data regarding depth to the clay barrier layer, no confirmation borings were required during construction. The specifications also required that the perimeter of the treatment area be completed first, to confine the MGP impacted area and minimize risk of MGP NAPL migrating outward beyond the treatment area boundary.

The ISS grout mix was specified to be 8% Portland cement and 1% bentonite. Although bench studies indicated that an alternative mix with 11% Portland cement without bentonite would also meet design performance requirements, but was not considered because the resulting high strength could potentially impede effective column overlap. The contractor was also allowed to develop alternative

grout mix designs. The initial water:reagent ratio was specified to be 1:1 by weight, but higher water to solids ratios could be used, if necessary. Auger mixing was specified; bucket mixing was not permitted.

The design required pre-excavation to a depth of 4 ft (1.2 m) prior to ISS treatment, corresponding to local frost depth. This pre-excavation would subsequently be backfilled with clean soil, protecting the top of the ISS monolith from degradation by freeze-thaw action. The precut also served to contain spoils during the work.

5.1 Means and Methods

Remedial ISS was performed by WRScompass, Windsor, NJ, between December 2010 and April 2011. ISS was performed using a 10-ft (3.0 m) diameter mixing auger powered by a crane mounted Diesel-Hain drill platform having 400,000 foot-pounds (540 kJ) of torque. Type I Portland cement was delivered to the site in pneumatic trucks and offloaded into storage pigs. Bentonite was delivered in 50-lb (220 N) bags. Grout was prepared using a high-shear mixer. The batch tank had a working volume of approximately 5 cubic yards (3.8 m³).

Required reagent quantities were calculated for each column considered its required depth and overlap with adjacent columns. The predetermined grout volume was pumped to injection ports located along the arms of the mixing tool and blended with the impacted soils. The 10-ft (3.0 m) diameter columns were positioned in a triangular pattern with nominal spacing of 8.67 ft (2.64 m), providing full coverage without gaps. Three vertical mixing passes were typically used, resulting in a homogeneous mixture of the impacted granular soils.

Initial trials indicated that the 8% Portland cement plus 1% bentonite grout mix was not pumpable when mixed at the initial 1:1 water:reagent ratio. To create a pumpable mix, the water to solids ratio was increased to 1.85:1. Since this would significantly increase the quantity of spoils (i.e., swell), the Contractor constructed several test columns to evaluate the feasibility of reducing the quantity of bentonite and water in the grout mix. These test columns indicated that the quantity of bentonite could be reduced to 0.75% (and possibly 0.5%), without significant increase in hydraulic conductivity and a substantial reduction of water. Based on these tests, the grout mix was modified to 8% Portland cement plus 0.75% bentonite, mixed at a 1.23:1 water to reagent ratio. The modification reduced the required quantity of reagents somewhat, but more importantly, reduced the required volume of water and resulting volume of ISS spoils, which required costly off-site disposal for this project.

ISS treatment (Figure 1) totaled 52,103 cubic yards (39,835 m³). Spoils (swell) amounted to approximately 21,180 tons (19,215 tonnes). This equates to approximately 25 percent spoils, assuming 1.6 tons per cubic yard.

Figure 1. ISS mixing operations

5.2 Quality Control

Treated material was sampled using a sampling tool with a hydraulically operated lid (Figure 2). The lid is opened after the sampler is lowered to the desired sampling depth, allowing the treated soil to flow into the sampling device. Representative samples were typically obtained at two or three depths within an ISS column, and these were subsequently blended to create a single composite sample for the column. Test cylinders were created from the composite sample after screening out larger sized particles. The test cylinders were stored and cured in a water bath in a heated room. At the end of the cure period, the samples were delivered to the test laboratory by courier. Laboratory testing was performed by Atlantic Testing Laboratories, Ltd., Canton, NY.

Figure 2. ISS sampling operations

A total of 113 Quality Control samples (Figure 3) were obtained by the design engineer (AECOM). Unconfined compression strength testing was performed at 7 days to provide an early indication of ISS performance. Unconfined compression strengths ranged from 39 to 351 psi (270 to 2,420 kPa), averaging approximately 180 psi (1,240 kPa) at 7 days. The standard deviation of the sample pool was 70 psi (480 kPa). Only one sample had strength less than the required 50 psi (345 kPa); however, its strength increased to 69 psi (475 kPa) at 28 days.

Hydraulic conductivity tests were performed at 28 days. Measured hydraulic conductivities ranged from 5×10^{-8} to 3×10^{-6} cm/s, averaging about 6×10^{-7} cm/s. The standard deviation of the sample pool was 5×10^{-7} cm/s. Ten samples failed to achieve the specified criterion of 1×10^{-6} cm/s at 28 days. Subsequent testing, however, demonstrated that the specified hydraulic conductivity was achieved with additional curing at 56 days. The data show that it would be necessary to target a design hydraulic conductivity of about 1×10^{-7} cm/s to ensure that practically all samples will achieve the required maximum allowable value of 1×10^{-6} cm/s at 28 days.

Figure 3. ISS sample (note gravelly nature of the sample)

6. NAPL RECOVERY

NAPL recovery activities began in 2009 with the installation of three recovery wells located on an off-site property downgradient to the former MGP property. These wells produced NAPL from a pooled depression in the clay confining layer. Four additional recovery wells were subsequently installed to tap the NAPL pool, and a recovery test using mechanical rotary pumps produced a total of approximately 19,000 gallons of NAPL/water mixture over a 9-day period. Several samples of the collected NAPL/water mixture were analyzed to determine their approximate water content. Each sample was weighed, placed in a dry oven for 24 hours, and subsequently weighed again. The results indicated that the collected NAPL/water mixture contained between 50% and 95% NAPL by mass.

Following the recovery test a recovery system was installed in 2010, including a series of bladder pumps controlled by an electronic controller connected to a compressor. The bladder pumps did not emulsify the NAPL with water as the mechanical rotary pumps had done, allowing the system to more efficiently collect NAPL while minimizing inclusion of water. The resulting NAPL/water mixture is believed to contain about 95% NAPL by mass. Three additional recovery wells were also installed within a second depression identified in the

confining clay layer during pre-design investigations in 2010. Current NAPL recovery is ongoing with a total of over 60,000 gallons (225,000 liters) recovered to date.

7. ISCO TREATMENT

Two vendors (VeruTEK, Bloomfield, CT, and XDD, Stratham, NH) were selected to perform ISCO treatability studies. XDD evaluated commercially available oxidants: activated persulfate and catalyzed hydrogen peroxide (CHP). VeruTEK evaluated proprietary surfactant-enhanced ISCO technology, Fe-EDTA activated persulfate, green synthesized zero valent iron (G-nZVI) catalyzed hydrogen peroxide, VeruSOL-3, and VeruSOL-11.

Based on the results of the XDD treatability study, a 12.5 percent solution of CHP with 20 mM citric acid and 3.5 g/kg acid was the most effective and reliable ISCO chemical for the Site. The treatability study indicated preferential treatment of BTEX (99%) and to a lesser extent PAHs and TPH (approximately 50%) after four applications of ISCO on moderately impacted soils. Approximately 20 lbs of oxidant is expected to be used per lb of contaminant treatment of moderately impacted soils. The XDD study also indicated that more applications will be required to treat the heavily impacted soils, and NAPL may smear from the contaminated intervals into less or non-contaminated intervals.

The VeruTEK treatability study indicated that VeruSOL-3 solubilized TPH more effectively than VeruSOL-11 and that S-ISCO efficiently oxidized COCs in the emulsion. Overall, G-nZVI CHP was the best performing oxidant/activator with reductions of 99% in VOCs, 96% in SVOCs, and greater than 66% reduction in TPH (DRO and GRO) concentrations relative to the control. The concentration reduction percentage can be misleading since VeruTEK failed to provide overall contaminant mass balance (i.e., contaminant concentration reduction due to treatment of the contaminants or flushing through the treatment cell could not be determined).

Based on the treatability study results, CHP will be used for full-scale ISCO injection for the treatment of off-site NAPL impacted area, upon completion of the NAPL recovery. Continued NAPL monitoring and recovery will be conducted during and following the ISCO injection. Follow-up soil and groundwater monitoring will be conducted for a period of up to 6 months to evaluate the effectiveness of ISCO.

8. CONCLUSIONS

- a. ISS successfully treated MGP impacted soil at the Norwich former MGP site, achieving the required unconfined compressive strength of 50 psi (345 kPa) at 28 days and maximum hydraulic conductivity of 1×10^{-6} cm/s at 28 to 56 days.
- b. Unconfined compression strengths ranged from 39 to 351 psi (270 to 2,420 kPa), averaging approximately 180 psi (1,240 kPa) at 7 days. The standard deviation of the sample group was 70 psi (480 kPa). All test results exceeding the specified minimum of 50 psi at 28 days.
- c. Measured hydraulic conductivities at 28 days ranged from 5×10^{-8} to 3×10^{-6} cm/s, averaging about 6×10^{-7} cm/s. The standard deviation of the sample group was 5×10^{-7} cm/s. Ten samples failed to achieve the specified criterion of 1×10^{-6} cm/s at 28 days. However, subsequent testing demonstrated that the specified hydraulic conductivity was achieved after 56 days curing.
- d. The volume of spoils (swell) was approximately 25 percent. This exceeded initial estimates, the increase largely caused by the need for additional water to improve grout pumpability. The greater volume of spoils resulted in cost overruns, as excess spoils required off-site disposal for this project.
- e. Selection of the design grout mix focused on achieving the required hydraulic conductivity in the gravel soils at this site, while also controlling strength gain so that column overlap could readily be achieved. This was accomplished by using bentonite in the grout mix. Although bentonite was clearly beneficial in reducing hydraulic conductivity and controlling strength, its use required increased water content, which increased the volume of swell and spoils. Effort should be made during bench studies and field trials to minimize the quantity of bentonite to control the volume of spoils.
- f. Consideration should be given to other potential reagents that may achieve suitable results, while reducing the required quantity of water (e.g., granulated blast furnace slag (GBFS)). Use of GBFS has successfully been used on other ISS projects with little or no bentonite addition (personal communication, WRS Compass). GBFS has also been used for other grouting applications, such as hydraulic cutoffs in bedrock (Weaver and Bruce, 2007).
- g. Significant NAPL recovery is potentially achievable. Detailed modeling of the surface of confining layers is useful to identify potential NAPL pools.

9. REFERENCES

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