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INNOVATIVE TECHNOLOGY FOR EXPEDITED SITE REMEDIATION OF EXTENSIVE SURFACE AND SUBSURFACE CONTAMINATION

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ABSTRACT

Large scale surface and subsurface contamination resulted from numerous releases of feed stock, process streams, waste streams, and final product at a major chemical plant. Soil and groundwater was contaminated by numerous compounds including lead, tetraethyl lead, ethylene dibromide, ethylene dichloride, and toluene. The state administrative order dictated that the site be investigated fully, that remedial alternative be evaluated, and that the site be remediated within a year period. Because of the acute toxicity and extreme volatility of tetraethyl lead and other organic compounds present at the site and the short time frame ordered by the regulators, innovative approaches were needed to carry out the remediation while protecting plant workers, remediation workers, and the public.

A combination of investigative techniques was used to determine the extent of LNAPLs, DNAPLs, and dissolved contaminants and to develop a geohydrologic model of the site. The investigative program consisted of an exhaustive soil-gas survey to map shallow contaminant plumes across the site, followed by shallow soil sampling, drilling and soil sampling, and installation of over 100 monitoring wells to investigate the top three transmissive zones. A plan to evaluate treatability of soils heavily contaminated with tetraethyl lead (TEL) was developed and implemented. The program included sampling heavily contaminated soils in level B personal protection, transporting the samples to a laboratory, performing an extensive treatability study, and developing field procedures to be implemented by the remediation contractor at the site. The treatability program consisted of evaluating the effectiveness of four oxidizers, selecting the most effective and practical oxidizer, developing a stabilization procedure for the treated waste to pass the paint filter test required for acceptance at the landfill,and developing methods to control fugitive emissions and odors during transport to an out-of-state disposal site.

This site being an active chemical plant dictated that the selected remedial action be compatible with the plant operations and be protective of the plant workers and public. Work Plan, Closure Plans and Specifications for remediation of the heavily contaminated soils in the active shipping and receiving area were developed. Unique, innovative solutions were found and implemented for containing fugitive emissions by enclosing remediation operations within a negative-pressure environmental enclosure, in situ and ex situ soil treatment to mitigate the sources, controlling groundwater, expediting backfilling of excavations through pumping low strength concrete directly into the excavations, and capping remediated areas with a specially designed, highly impermeable HMAC mix. This innovative capping approach reduced construction costs by over 40 percent and provided caps which did not interfere with ongoing plant operations.

A strict and extensive program of QA/QC, health and safety, emissions monitoring and remediation confirmation was carried out through the use of an on-site, mobile laboratory operating 24-hours a day and running analyses using full EPA and biomedical protocols. Over a three-month period, approximately 2000 soil, 1200 water and groundwater, 750 air, and 2500 urine samples were collected and analyzed. Three-hour to 24-hour turnaround times were provided for 95 percent of the samples. Oversight, construction management, and closure certification were provided for the remediation program.

I. INTRODUCTION

Until the 1950s the plant area consisted of natural marsh land. The plant area was filled with dredge spoils (i.e., sands, silts, and clays) resulting from the widening and deepening of the nearby Neches River channel to maintain open shipping lanes. This reclaimed area became an ideal place to site new petrochemical plants and refineries in the early 1960s. The plant which is the subject of this paper was constructed at that time to manufacture motor fuel antiknock compounds (e.g., tetraethyl and tetramethyl lead).

The process used at this particular plant to manufacture tetraethyl lead (TEL) consisted of the following basic steps:

- Receiving one-ton lead ingots, commonly referred to as lead pigs, via rail and barges;

- Melting the ingots in a smelter at the bottom of a seven story reactor building;

- Pumping the molten lead to the seventh story of the unit and pouring it onto a rotating turntable;

- As the lead solidified on the rotating table, shaving the lead by a tool which operated in a fashion similar to that of a lathe;

- Bringing the lead shavings into a high pressure, high temperature autoclave where they were mixed with an organic liquor, thereby promoting the attachment of lead atoms to the organic molecule.

Lead contamination of the site resulted from a variety of sources and events, such as:

- Inadvertent dropping of lead pigs during unloading, which readily sank into the marshy soils;

- Gradual sinking of stockpiled ingots;

- Periodic blowing of autoclave pressure plates resulting in the raining of lead shavings across the entire site;

- Inadvertent spills of TEL while filling tank cars and barges;

- Rupturing of vessels and storage tanks which lacked impermeable secondary containment;

- Improper disposal of off-spec material;

- Discharge of process waters and free product in unlined storm water ditches;

- Leakage from sumps, settling ponds, clarifiers, and equalization ponds.

The lead plant was dismantled in the early 1980s, when leaded gasoline was being phased out. Concurrently new units were built for the manufacture of other petrochemicals. Thus, operations never ceased at the plant.

II. REGULATORY ENFORCEMENT AND CONSENT ORDER

In the mid 1980s, the state regulators ordered that the nature and extent of contamination at the site be assessed. Surface, subsurface (geologic and hydrogeologic environments) were characterized through an extensive program consisting of the following elements:

- comprehensive review of plant history and operations;

- passive soil-gas survey (over 200 points across the entire site);

- surface soil sampling (at 100s of locations);

- storm and process water conveyance system sampling;

- shallow soil sampling (at 100s of locations);

- soil borings to define stratigraphy and sample the upper three transmissive zones (at 100 plus locations);

- cone penetrometer probings (at 30 plus locations);

- monitor wells to assess nature and extent of contamination in upper three transmissive zones (at 200 locations); and

- hydrogeologic characterization by slug tests and long duration pump tests, as well as surveys of the tidal influence on groundwater flow.

A risk assessment was performed to assess the potential impact of site conditions on human health and the environment. Both forward and backward risk projections were made as part of the modeling effort. Acceptable levels of lead in the site soils were determined from the risk assessment.

A consent order was negotiated using the risk-based levels as goals and guidance for remedial action. Trigger levels were established for implementation of contingency plans for contaminant levels in groundwater at the plant perimeter and internal areas. The consent order required that the following tasks be completed:

- installation of an internal plant monitoring well system with a quarterly monitoring program to check for trigger levels;

- installation of a plant perimeter monitoring system with a quarterly monitoring program to check for trigger levels of contaminants and off-site migrations;

- remediation of four hot spot areas of lead contamination by removal of the most contaminated surface soils and capping of the four areas;

- remediation of the extensive organic lead contamination in the shipping and receiving area by removal of the most contaminated surface soils and then capping of the area;

- completion of the closure of the former sludge settling basin; and

- completion of the decommissioning and decontamination of any remaining facilities from the former lead plant and decontamination and refurbishing of storm water handling facilities.

III. MONITORING SYSTEM

A groundwater monitoring system was designed to detect the presence of contaminants at hot spots internal to the plant and to check for off-site migration around the entire plant perimeter. Nested wells were installed in the top three transmissive zones at 30 locations on-site and 3 locations off-site. All well installation work was conducted in Level B personal protection equipment. For the first five years, the wells associated with this monitoring system were sampled quarterly. Contaminants of concern in the groundwater were lead, organic lead, EDB, and EDC.

IV. CAPPING OF FOUR HOT SPOT AREAS

Four areas identified in the surface and shallow sampling programs had extensive inorganic lead contamination within the top two feet of soil which was above the site-specific, risk-based standards established during the consent order negotiations. The consent order required that the soil above the acceptable limits be removed and properly disposed, that the area be backfilled with clean fill, and that an impermeable cap be placed over the entire area where the contamination was found.

Conventional clay capping techniques could not be employed since the areas to be capped were in the middle of active areas of plant operations. It was not possible to build 3-foot thick clay caps with five percent slopes in these areas. In order to achieve the capping requirements and permit plant operations to continue, new standards were developed for capping the area with a special, rich, hot asphalt mix design, coupled with specifications to guarantee less than 2 percent air voids in the asphalt cap. The asphalt caps needed to have the following qualities:

- very low permeability with a good run-off surface;

- sufficient strength to support plant vehicle traffic;

- durability and low maintenance requirements;

- ease of construction.

In order to achieve these characteristics, the following minimum specifications were developed:

- dense-graded surface course (100 percent passing the 0.5-inch sieve) conforming to state department of transportation master gradings;

- maximum two percent air void content;

- minimum 95 percent in-place compaction; and

- measured permeability lower than 1×10^{-7} cm/sec.

Special permeability tests were developed, using flexible wall permeameters, to demonstrate that the asphalt greatly exceeded cap requirements (actual measured permeabilities were on the order of 6×10^{-11} cm/sec). Excellent run-off and permeability several orders of magnitude lower than that required for conventional clay caps helped gain acceptance of the asphalt capping technique by the regulatory agencies.

In each of the four areas, the top 2 to 2.5 feet of soil was removed. The excavated soil was characterized and disposed at a hazardous waste landfill facility. The bottom of the excavation was sampled to document the lead levels left in the soils. Clean fill was placed in the excavation to create the proper grade on which to place the asphalt. The asphalt cap then was installed following rigorous specifications. In order to comply with strict environmental standards, a rigorous quality assurance/quality control program was implemented. Temperature checks were made of each truck load, and extraction and gradation tests were made at specific intervals. In place density and air voids were checked on a tightly spaced grid. A simple field indicator showing that air voids approached zero was noted by the tendency for the asphalt to bleed slightly at the surface at the end of pneumatic compaction.

V. SHIPPING AND RECEIVING AREA REMEDIATION UNDER AN ENVIRONMENTAL ENCLOSURE

Remediation of the shipping and receiving area of the plant involved a variety of issues and complexities as a result of the presence of significant amounts of organic lead contamination and the fact that the area gets regular heavy use. The area is located at the plant boundary, adjacent to a public road which receives heavy use by traffic to and from other plants and by joggers. An approach needed to be developed to permit remediation of the area without exposing plant workers or the public to organic lead and without interrupting the functions of shipping and receiving which are integral to the plant's operations. In order to achieve these goals, the concept of conducting the operations in a negative-air enclosure was developed.

Other constraints on the remedial action included:

- the presence of groundwater six inches beneath the surface, which made dewatering necessary in order to perform the required excavation;

- requirements to handle large amounts of contaminated groundwater within the constraints of the plant's NPDES permit;

- the capacity to handle large volumes of storm water; since the work was conducted during the hurricane and rainy seasons; and

- meeting railroad safety standards for conducting construction work in close proximity to active railroad tracks where tank cars were being shuttled back and forth.

The contamination in the shipping and receiving area resulted from numerous small spills which accumulated over time and from one very large spill which occurred when a 20,000 gallon tank holding organic lead product ruptured. The contaminated area was approximately 400 feet long and 60 feet wide.

In order to determine the types of treatment required to perform the remediation, large samples were collected during slow shift, weekend hours for use in a treatability study. The treatability study was conducted to determine the type of treatment required and the recipe for materials to be mixed with the contaminated soil to make it suitable for transport and landfilling.

To serve as the enclosure, a pre-fabricated structure was selected which consisted of an aluminum frame with a reinforced HDPE skin. The building frame was anchored to the ground to resist forces generated by hurricane winds up to 125 miles per hour. The enclosure was outfitted with personnel entry and egress air locks, emergency exits, as well as an equipment air lock capable of handling semi-trailer dump trucks and associated decontamination pad. The interior of the enclosure was maintained at pressures slightly below atmospheric through an air handling system capable of turning over the volume of air in the building at least four times per day. The exhaust was passed through a three-stage activated carbon scrubber, which operated at a minimum efficiency of 97 percent.

As a result of the high levels of TEL contamination in the atmosphere inside the enclosure, all work was conducted using supplied air equipment (PPE Level B). Three semi-trailer cascades supplied breathing air to the inside of the enclosure, where headers had been strategically located, for all inside workers. Oversight personnel operated using SCBAs because of their need to have greater mobility and access to the entire building at any given time.

An extensive health and safety program was implemented, including continuous air monitoring inside the enclosure, at the air handling system exhaust, within the plant, and along the road. Personnel were given blood tests for lead and had urine analyses conducted at least once daily for lead.

A dewatering system was set up both inside and outside of the enclosure to depress the groundwater to a depth 2 feet below the target excavation depth. As a result of the space limitations inside the enclosure, it was necessary to excavate the soil in 40 foot by 60 foot plots. After collecting documentation samples and surveying the bottom of each plot, each excavated plot was backfilled by pumping a low-strength concrete through a hose passed under the enclosure wall. Once the concrete was set, the soil was treated through a land farming operation in which it was mixed thoroughly with a saturated, aqueous solution of potassium permanganate to oxidize the organic lead. The soil was then stabilized by adding a special cement/fly ash/lime mixture to make the material ready for transport and disposal at an off-site hazardous waste landfill.

When the excavation and treatment were completed, the atmosphere was thoroughly purged of contamination through the air-handling system. The equipment was decontaminated and the decontamination process was confirmed by conducting wipe tests, before any equipment was removed from the site. The enclosure then was dismantled; the skin was disposed; and the frame was thoroughly decontaminated.

Cement stabilized sand was placed over the concrete backfill and shaped to the appropriate grade as a sub-base for the asphalt cap. A highly impermeable, asphalt cap was placed over the area, in a manner similar to that discussed for the other areas.

A strict and extensive program of QA/QC, health and safety, emissions monitoring and remediation confirmation was carried out through the use of an on-site, mobile laboratory operating 24-hours a day and running analyses using full EPA and biomedical protocols. Over a three-month period, approximately 2000 soil, 1200 water and groundwater, 750 air, and 2500 urine samples were collected and analyzed. Three-hour to 24-hour turnaround times were provided for 95 percent of the samples. Oversight, construction management, and closure certification were provided for the remediation program.

A materials testing laboratory also was set up on-site to provide the QA/QC tests on the concrete backfill, the cement stabilized sand, and the asphalt mix. In addition, in situ tests, such as temperature and in place density, were performed to confirm that the specifications for the cap and sub-base material had been met.

V. SETTLING POND CLEAN CLOSURE

At the time of the lead plant decommissioning, an above grade settling pond was decommissioned. The liquid contents of the pond were pumped and disposed, as were all sludges from the pond bottom and sides. The remaining, uncontaminated clay which formed the containment dikes was regraded to fill the pond and for use as a clay cap. Monitoring wells were installed around the pond perimeter to assess whether statistically significant levels of contaminants were present.

Three years of monitoring well data were evaluated in accordance with EPA guidelines for statistical analyses in support of clean closure of the pond. Once the clean closure application was accepted, the cap was completed by grading the clay to appropriate slope to promote drainage and minimize infiltration; adding a layer of top soil; and seeding and sodding of the area to create vegetative cover and reduce erosion.

VI. TEL SLUDGE LINE DECOMMISSIONING

During the TEL plant operation, a 14-inch diameter pipeline carried TEL sludges produced within the plant from the clarifier to the settling pond discussed previously.

This line was the last element of the lead plant which needed to be decommissioned. The line was located in the middle of a pipe rack which contained a number of other lines which were integral to the current operation of the plant.

The following plan was devised to remove the pipe without interrupting plant operations and with minimal potential exposure to plant workers and remediation workers:

- the sludges were sampled and analyzed, and the results showed that approximately two thirds of the sludge was inorganic lead and one third was organic lead;

- a continuous nitrogen purge was placed on the line to make the atmosphere inert and thus minimize potential for explosion;

- the pipeline was place on rollers so that it could be pulled along easily;

- a cherry picker outfitted with a special sling was used to pull the pipe out of the rack in 3-foot increments;

- remedial construction personnel, outfitted with supplied air, used cold cutting tools, well-oiled to prevent sparking, to cut off three-foot long sections of the pipe over an area covered with an HDPE secondary containment to control spills;

- sections of pipe were capped at both ends and taken to a special staging area where they were placed inside large cylindrical forms, similar to those used for casting concrete columns;

- a specially designed cement/bentonite grout was poured into the pipes, and in the annulus between the pipe sections and the forms, to stabilize and fully encapsulate the pipe sections and the sludges;

- once the grout had set, the encapsulated pipe sections were transported by truck to a hazardous waste landfill, for final disposal.

VII. MONITORING AND MAINTENANCE OF CLOSED FACILITIES

A plan for monitoring and maintenance of the closed facilities was developed and implemented in accordance with the consent order. The monitoring wells in the perimeter and internal monitoring systems are sampled quarterly. Data are processed and reviewed in accordance with consent order requirements.

Capped areas are inspected annually and maintained as needed to ensure their compliance with state and federal regulations and consent order requirements.

VIII. SUMMARY

The entire program described herein was completed in three years. All of the deadlines specified in the consent order were met. By developing new and innovative approaches for use and application of existing technologies, substantial savings of time and money were realized by the client (savings ranged from 20 to 40 percent of the client's cost projections on different parts of the project). Application of proven technologies in new ways made it possible to obtain acceptance from regulatory agencies of new approaches. These successes were made possible by having a small core team of senior professionals managing the project and providing technical input from characterization through remediation. The same core project management team of two persons, a geologist and a civil engineer, and senior advisory staff, a modeler and risk assessor conducted the technical work and handled interactions and negotiations with the agencies involved. This was the first project of this type and scale to be conducted using a negative-air enclosure and one of the first places where asphalt capping gained regulatory acceptance.