COST-EFFECTIVE DESIGN OF A TREATMENT SYSTEM FOR CLEANING UP SOILS AND GROUND WATER CONTAMINATED WITH PETROLEUM HYDROCARBONS

Elio F. Arniella, P.E.

AUTHOR: Elio F. Arniella, P.E. Envirosoft, P.O. Box 862188, Marietta, Georgia 30062-0001

REFERENCE: Proceedings of the 1991 Georgia Water Resources Conference, held March 19-20, 1991, at The University of Georgia. Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia.

INTRODUCTION

Today, it is not uncommon to drive around your neighborhood and notice that the corner gasoline station is out of service for several days for replacement of underground tanks. In fact, leaking underground tanks are responsible for contaminating the ground water supplies of many communities in the United States. What was a common practice in previous decades -- burying a single wall steel tank that is exposed to corrosion -- is becoming a major liability to an industry that depends on the use and underground storage of petroleum hydrocarbons.

This paper presents general soil remediation technologies and includes a case study of a cost-effective design of a remediation project in Georgia.

The U.S. Environmental Protection Agency (EPA) estimates that three to five million underground storage tanks (UST) are used in the nation for storing petroleum hydrocarbons and chemical substances. Estimates indicate that a large quantity of these tanks, 100,000 to 400,000, may be leaking petroleum hydrocarbons (U.S. EPA /0530 /UST-88/001). Releases from UST can result in the contamination of subsurface soils, migration of toxic and explosive vapors, and pollution of surface and ground waters. The degree of contamination and human health and environmental exposure depends on: (1) the amount of fuel released; (2) the chemical and physical properties of the material; (3) the hydrogeologic conditions of the site and resulting migration patterns; and (4) the levels of exposure to potential receptors.

CLEANUP PROCEDURES

The process for cleaning up petroleum hydrocarbon releases involves three steps: (1) removal of free product found floating in the water table, (2) removal of petroleum hydrocarbons adsorbed by the soils and/or sediments, and (3) removal of the soluble and emulsified fraction of petroleum hydrocarbons found in the water.

The case study summarized herein is based on the remediation of a gasoline leak from an UST site in the metropolitan Atlanta area. The success of this project was a result of being able to meet all State of Georgia UST cleanup criteria in a very cost-effective manner.

The site is used by a trucking company as a truck and trailer storage lot and as a maintenance facility. Activities on site have included truck repair and maintenance inside a garage, truck and trailer washing over a pad outside the building, and fueling of company automobiles by means of an underground gasoline storage tank and a dispenser. A test of the gasoline tank revealed that leakage had occurred into the underlying soil and ground water. When the leaking UST was removed, the gasoline constituents were detected laterally in the vicinity of the excavation (10 ft. radius) and vertically reaching the water table. The tank and piping were removed and the most highly contaminated soil was excavated. The depth to ground water (approximately 30-35 feet) and quantity of contaminated soil precluded complete removal as a viable option. The excavation was filled with clean soil and a concrete pad was poured over the area. Adjacent areas are topped with four inches of asphalt.

Cleanup Criteria

The Georgia Underground Storage Tank Act stipulates the following specific UST remediation criteria:

1. If the public drinking water wells owned by local, State or Federal governments exist within three miles or if privately owned drinking water wells exist within one-half mile, the UST owner or operator must: (a) remediate soil contamination that exceeds 100 milligrams per kilogram (mg/Kg) of total petroleum hydrocarbons (TPH) or 20 mg/kg of total Benzene, Toluene, Ethylbenzene, and Xylene (BTEX); (b) remove visible free product; and (c) remediate ground water contamination that exceeds the Maximum Contaminant Level (MCL); and

2. At other UST corrective action sites, the UST owner or operator must: (a) remediate soil contamination that

exceeds 500 mg/Kg TPH or 100 mg/Kg total BTEX; (b) remove visible free product; and (c) monitor contaminant plume movement.

Since no drinking water wells are present in the specified area of the case study, the UST site remediation is governed by the second set of requirements.

Soil Remediation Technologies Considered

Remediation technologies applicable to removal of petroleum hydrocarbons from soils include: (1) excavation/offsite disposal, (2) soil stripping/venting, (3) biodegradation/landfarming, (4) thermal desorption, (5) solidification/stabilization, and (6) soil flushing. Of these technologies, a combination of excavation and offsite disposal and air stripping or in-situ soil venting was determined to be the most cost-effective alternative.

Description of the Selected Alternative

Factors that contributed to the selection of this alternative include:

- Lowest capital and O&M cost
- Fast construction
- Effectiveness in meeting the cleanup criteria
- Less interruption of current operations
- Low maintenance requirements

Excavation with offsite disposal was considered as a stand-alone alternative, but the depth of the excavation, volume of material to be removed, and interruption of existing operations at the facility were factors against the selection of this option. Instead, a limited volume of soils contaminated with gasoline at levels of about 2500 mg/Kg of TPH were removed and disposed offsite.

Air Stripping/ Soil Venting System

This technology offers a cost-effective method to remove volatile organics present in the unsaturated zone. The process works by enhancing volatilization of organics within the subsoil, and it air-strips the contaminated soils in place. A subsurface vacuum attracts vapors in the soil to a series of extraction wells. The phenomenon that permits stripping of volatile organics from the soils can be best described as a controlled disequilibrium in the soil/gas interphase. Because non-contaminated and non-saturated air is pulled through the contaminated zone, the partial pressure of the contaminant (in the surface of the soil particle) is lowered. Applying Henry's Law under these conditions implies that VOC contaminant molecules will predominantly move from the soil to the gaseous phase and the contaminants are removed. Henry's Law can be expressed mathematically as:

$$P_A = H_A X_A \qquad \text{(Equation 1)}$$

where:

P_A = Partial vapor pressure of a compound A in the soil matrix when in equilibrium with air (atm)

H_A = Henry's Law constant (atm)

X_A = mole fraction of the compound A in soil (mole/mole)

Process Design

The process design concept is to surround the area where soil contamination exceeds the cleanup criteria with air extraction wells. Ten 2-inch diameter PVC wells were located in the periphery of the designated area and were screened above the water table elevation (about 35 feet). Each well has a vacuum gauge, a sampling valve, and a flow regulator valve. Off-the-shelf materials and equipment were exclusively used in the design. The blower unit used was a portable vacuum unit typically used in shop operations. This 5-Hp unit has a 250 cubic feet per minute (cfm) capacity. The extracted air is vented to the atmosphere. The unit meets the local air quality requirements without additional treatment of the air stream. A process schematic diagram is presented in **Figure 2**. This particular system was designed and built for under $28,000. This cost included engineering, materials, equipment, installation, electrical, and control expenses.

Process Performance

The unit is currently being tested for full time operation. Preliminary data collected during start-up is presented in **Figure 2**.

The results expressed in this figure were calculated using a hand-held, battery operated Alnor Eco Series Micro Manometer with an attached Pitot tube to measure the air flow. This instrument is inserted in the suction pipe of the blower system at a specially designed port. A continuous digital readout of the velocity is obtained and converted to air flow. The concentration of VOCs presented in Figure 3 were obtained using a Photoionization Meter (HNu^{TM}). In addition, samples to be analyzed for specific BTEX compounds were collected at several time intervals using a battery operated Supelco^{TM} Sampler Pump with an ORBO^{TM} Tube. This particular instrument pumps air from the contaminant stream at a pre-set flow rate through a glass tube that has a mini carbon adsorption column. VOC components were

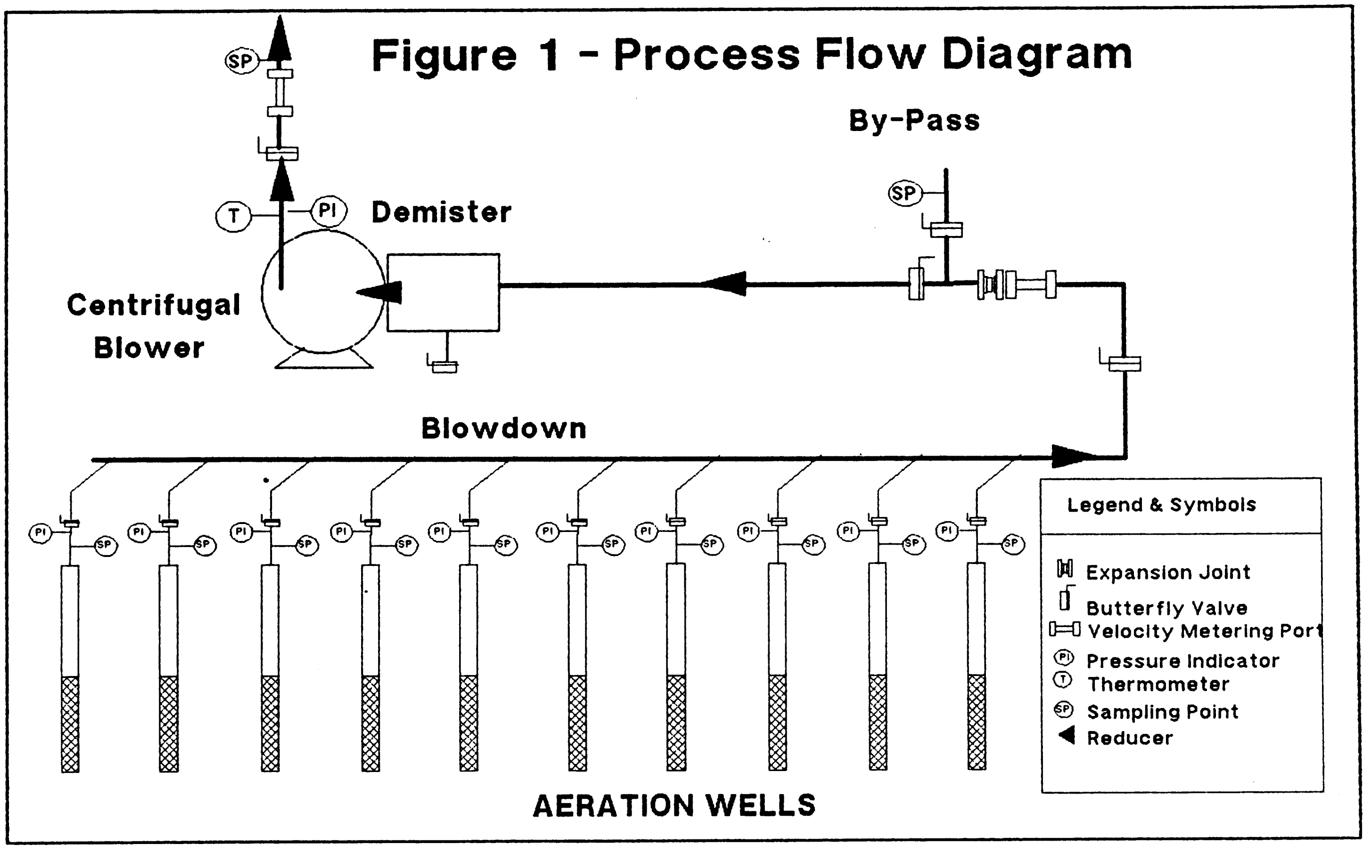

Figure 1 - Process Flow Diagram

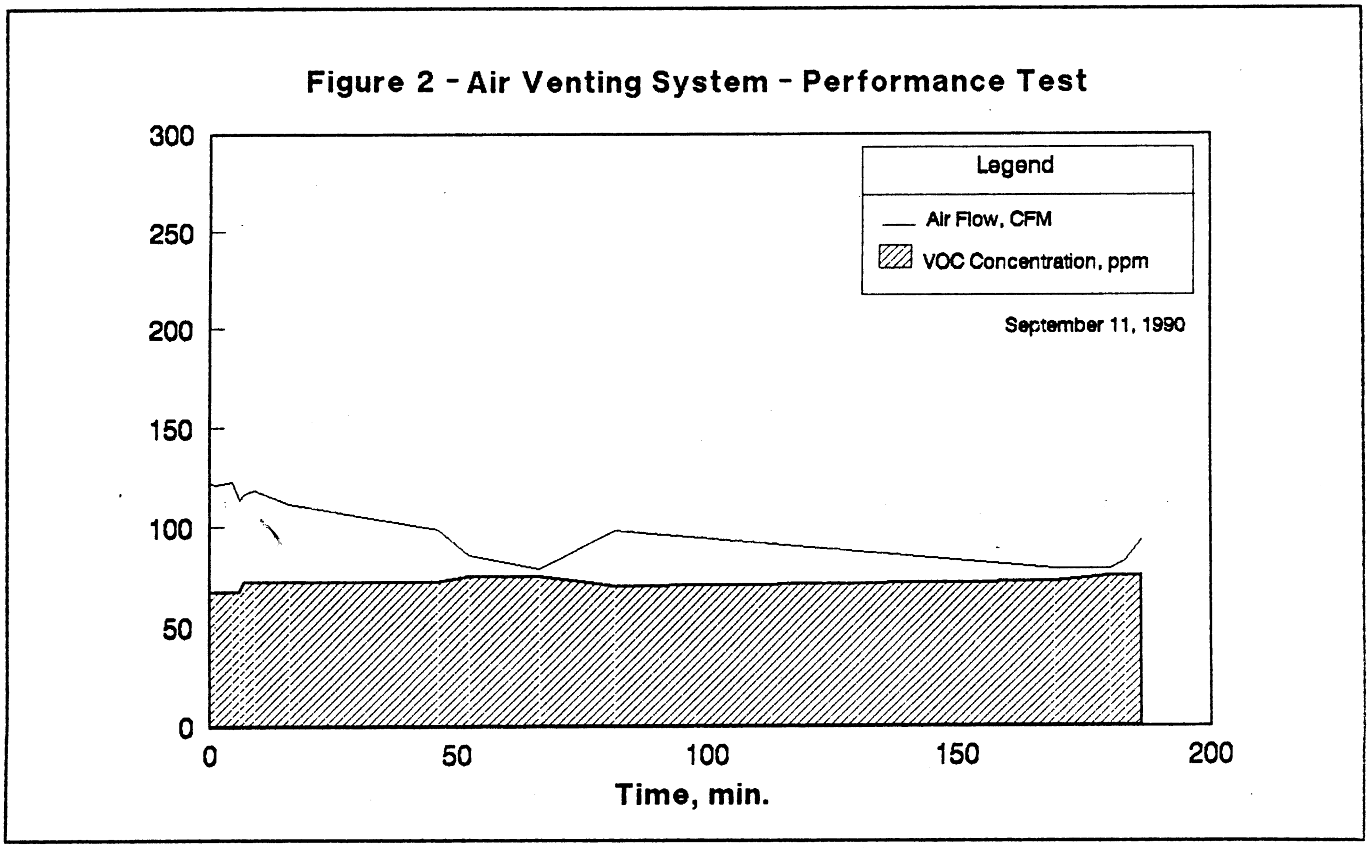

Figure 2 - Air Venting System - Performance Test

captured in the carbon column and sent to the laboratory for analysis. Results were not available at the time of printing of this paper. During startup, all air extraction wells measured a vacuum of about 5 inches of mercury (Hg). All wells can be sampled individually and the air flow can be adjusted or shut off as needed.

CONCLUSIONS

The in-situ venting system described in this paper represented the most cost-effective alternative for removal of BTEX components from the contaminated soils at the site. The system, including the air extraction wells, was designed and built for about $28,000 and uses off-the-shelf equipment. Based on startup performance tests, it is anticipated that the system will withdraw about 1 pound per day of gasoline-derived BTEX compounds and that the cleanup goals will be achieved in approximately 18 months.

In cases where ground water remediation is necessary, this system can be used effectively in removing a significant portion of the leachable fraction of VOCs adsorbed to soils.

LITERATURE CITED

Arniella, E.F., "Air Stripping Design Model for Removal of Volatile Organic Compounds in Ground Water", Proceedings of the VII International Conference on Chemistry for the Protection of the Environment", Polytechnic of Lublin, Poland, September 4-7, 1989.

Hawly, G. "The Condensed Chemical Dictionary", Tenth Edition, Van Nostrand Reinhold Co., Inc., New York, 1981.

Nyer, E.K. and Skladany, G.J., "Relating the Physical and Chemical Properties of Petroleum Hydrocarbons to Soil and Aquifer Remediation", Ground Water Monitoring Review, Winter 1989.

Nyer, E.K., "Treatment of BTEX Compounds at Low Flow Rates", Ground Water Monitoring Review, Spring 1988.

Patterson, J.W., "Industrial Wastewater Treatment Technology", Second Edition, Butterworth Publishers, Stoneham, MA, 1985.

Perry and Chilton, "Chemical Engineer's Handbook", Fifth Edition, McGraw-Hill Co., New York.

U.S. EPA, "Cleanup of Releases from Petroleum USTs: Selected Technologies", EPA/0530/UST-88/001.

U.S.EPA Public Health Evaluation Manual, Oct. 1, 1986.