A Rational Approach to the Remediation of Soil and Groundwater at Manufactured Gas Plant Sites

Richard A. Brown, Mike Jackson, and Mike Loucy
Groundwater Technology, Inc., Trenton, New Jersey, USA

Manufactured gas plant (MGP) sites represent a formidable remediation challenge due to their complexity. First, the base contaminant – coal tars – is composed of a complex mixture of polyaromatic hydrocarbons (PAHs) which, as a class of compounds, generally have low volatility, low solubility, and low biodegradability and are, therefore, are difficult to treat. Second, the mixture of PAHs present in coal tar is highly variable so that technology(s) that works at one site may not be as effective at another site. The variability in coal tar composition is a function of the type of coal used and of the type of gasification process employed. Generally, soft coals and the older 'water-gas' processes produced coal tars with less condensed (fewer ringed) PAHs; while hard coals and the more recent 'pyrolitic' processes produced coal tars with more condensed, multi-ringed PAHs. Third, there is a wide range in the depositional history and levels of the coal tars. Coal tars were spilled, used to provide impermeable bottoms to gas holders, and dumped in lagoons, on the ground, and in tar wells. It is not uncommon to find on the same site soil concentrations ranging from the tens of percent level to the part-per-million level. Also, with the wide range in level of deposition and in tar composition, coal tar liquids can be present as both LNAPLs (light non-aqueous phase liquids) and DNAPLS (dense non-aqueous phase liquids). Given this complexity of contamination, it is a commonly held belief that there are no technologies available to remediate these sites short of massive excavation and extensive groundwater pumping and treatment. And even where such effort has been employed, the results have often not met the remedial goals.

While the lack of remediation technology has been a problem for many years, there is an increasing number and variety of technologies and approaches available for the remediation of MGP sites. These fall into four main categories – thermal processes, desorbtion processes, biological processes, and chemical oxidation processes. The following is a brief description of many of the processes that have been recently applied or are being tested and developed for MGP sites.

Co-burning – Highly contaminated soils and coal tar liquids are mixed with combustible materials (e.g. crushed coal, wood chips) to form a fuel which is utilized in an industrial boiler.

Thermal desorbtion – Coal tar contaminated soils are thermally treated to volatilize and remove the coal tars. An innovative process developed by Seaview produces a low grade fuel oil.

Thermally enhanced product recovery – Heat is applied *in-situ* to contaminated soils with steam, hot air or RF/EMF energy to reduce the viscosity of sorbed coal tar liquids. At a lowered viscosity, the residual saturation is lowered and more of the coal tars can be recovered.

Clean soil process (CSP) – Coal tar contaminated soils are 'scrubbed' with a pulverized coal slurry. The coal tar is absorbed onto the coal, which is separated from the cleaned soil and collected as a burnable fuel.

Surfactant flushing – Blends of surfactants used with conventional soil washing equipment have been found to desorb PAHs from soils, reducing starting concentrations of ~3-5% to less than 500 mg/kg total PAHs.

Foam flushing – Foams produced with surfactants and air can physically displace and remove adsorbed PAHs.

Magnetically enhanced bioremediation – Bacteria grown under a unipolar magnetic field are able to more readily metabolize complex PAHs. The degradation of PAHs under a magnetic field is both accelerated and expanded from the simple 2 to 3 ring PAHs to the more complex and recalcitrant 4 to 6 ring PAHs.

Surfactant assisted bioremediation – A primary cause of the low degradability of many complex PAHs is their lack of solubility. Most bacteria require a soluble substrate in order to pass through their cell membrane. Surfactants can increase the solubility and therefore the biodegradability of many PAHs.

Fungal biodegradation – Fungi utilize extracellular enzymes to cleave complex structures and thus make them more metabolically available. Thus, fungi are able to biodegrade complex PAHs that are extremely recalcitrant to normal bacterial based processes.

Chemical biological treatment – In this GRI/IGT process soils and/or groundwater contaminated with PAHs are pretreated with a strong oxidant such as hydrogen peroxide. The partially oxidized PAHs are then more readily biodegraded.

In-situ ozonation – Ozone gas will directly oxidize and destroy PAHs sorbed to soils. It can be applied to both saturated and unsaturated soil matrixes.

The key to the successful application of these technologies, in addition to more conventional technologies, is understanding where they most effectively apply in the remediation of MGP sites. The effective use of these, as well as more conventional technologies is a function of the degree of contamination and the level of treatment desired. There are three levels of treatment that these technologies can achieve. The first is gross reduction where high levels of contamination are reduced so that the residuals no longer pose an immediate or acute health and safety threat. The second level of treatment is to control the continued migration of the PAHs by reducing the soil concentration to a low-leachable level. The last level of treatment is to 'clean', where a specific (or negotiated) standard for soils and/or groundwater is met. There are two 'clean' levels included in the matrix, reflecting industrial use and residential use. Some technologies are more appropriate for high levels of coal tar contamination but will only cost-effectively achieve a gross reduction. Other processes are capable of achieving low residual levels but work best with low starting concentrations of PAHs. Optimal treatment of an MGP site may require sequential operation of several processes. The following matrix gives an overview of remedial technologies that may be employed at an MGP site. The matrix is organized by level of contamination and by treatment goal.

As can be seen from this matrix, physical and thermal processes work best with high concentrations and are able to achieve moderate treatment goals. Biological and chemical treatment processes are best applied to moderate to low initial contaminant levels but are able to achieve rigorous treatment goals. Remediation of MGP sites involves selecting the proper mix and sequence of technologies. Breaking the site down into levels of contamination and treatment goals provides a rational framework for remedial planning. The issue is not whether there is technology available but can it be used effectively to achieve desired results.

Remediation Technology Matrix for MGP Sites

Desired level of treatment	**Sludges and liquids >10 000 mg/kg**	**Soils 1000 to 10 000 mg/kg**	**Soils 100 to 1000 mg/kg**	**Soils < 100 mg/kg groundwater**
Gross reduction <500 mg/kg	Co-burning CSP Thermal desorb Thermal product recovery Surfactant washing	Co-burning CSP Thermal desorb Mag. enhanced bio Surfactant washing Foam flush	Not applicable	Not applicable
Stabilization <100µg/L leachable	Co-burning CSP Thermal desorb Surfactant washing	Co-burning CSP Thermal desorb Mag. enhanced bio Surfactant washing Foam flush	Fungal remediation Surfactant washing Mag. enhanced bio Surfactant bio Chemical biological treatment Foam flush Ozonation	Mag. enhanced bio Chemical biological treatment Ozonation
Soils < 100 mg/kg **Groundwater <1,000µg/L (Industrial)**	Not applicable	Mag. enhanced bio Chemical biological treatment Surfactant bio	Fungal remediation Mag. enhanced bio Chemical biological treatment Surfactant bio Ozonation	Mag. enhanced bio Chemical biological treatment Surfactant bio Ozonation
Soils <1000µg/kg **Groundwater <100µg/L (Residential)**	Not applicable	Mag. enhanced bio Surfactant bio	Mag. enhanced bio Chemical biological treatment Surfactant bio Ozonation	Mag. enhanced bio Chemical biological treatment Surfactant bio Ozonation