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Specificities of former gasworks:

Comparison between French and English methodologies

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Abstract

This report compares two methodologies, French and English. The study of two sites located in Great Britain illustrates the methods and principles used. For confidential reason, the names and the location of the sites will not be given.

These two sites are related with former gasworks, they both received facilities from manufactured gas plants. Once the site was no longer required for gas manufacture, the gas plants were sold, the facilities demolished and the site redeveloped but sometimes by-products and/or wastes were not removed to the standard required in the present day. Once the local authority or contaminated land officer was aware of the potential contamination, the site goes through contaminated land management in order to assess if the site poses a risk to human health or controlled water. If a risk exists then a way to remediate either to take off the contaminated land or water or to treat directly on-site must be found to remove the risk.

The studied sites are both treated on-site. An innovative project was created to remediate the groundwater for the first site. This biological treatment has operated successfully since 2004. My mission was to monitor and to sample the groundwater.
A by-product (Blast Furnace Slag) had been utilised on the second site for building road as a sustainable alternative to quarried stone, its use had generated pollution. For this site I had to undertake a controlled water risk assessment, which involved a desk based literature review, sampling and investigations.

The both methods are closed but few tools or guidelines differ. For this work I was able to collaborate with Gaz de France, a senior member of staff at the BRGM and a senior member of staff at MEDDE (Ministère de l'Ecologie, du Developpement durable, et de l'Energie). These meetings were very interesting and helpful and allowed to understand the directives used in France.

Glossary

Acronym	Definition
BFS	Blast Furnace Slag
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BRGM	Bureau de Recherches Géologiques et Minières
CLM	Contaminated Land Management
DNAPL	Dense Non Aqueous Phase Liquid
DWS	Drinking Water Standards
EA	Environmental Agency
EQS	Environmental Quality Standards
ERA	Environmental Risk Assessment
GAC	Generic Assessment Criteria
GAC	Granular Activated Carbon
GDF	Gaz de France
HRA	Health Risk Assessment
MBGL	Meter Below Ground Level
MEDDE	Ministère de l'Ecologie, du Développement Durable et de l'Energie
NAPL	Non Aqueous Phase Liquid
PAH	Polycyclic Aromatic Hydrocarbons
PB	Parsons Brinckerhoff
PPE	Personal Protective Equipment
PRB	Permeable Reactor Barriers
SEREBAR	Sequential Reactive Barriers
SSRA	Site Specific Risk Assessment
TPH	Total Petroleum Hydrocarbons
UST	Underground Storage Tank
US EPA	United States Environment Protection Agency
UK	United Kingdom
WQS	Water Quality Standards

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Introduction

The main purpose of this internship is to investigate many sites in order to compare English and French methodologies and practice involved with the investigation and remediation of contaminated soils on former gasworks. This has a particular focus on the fate of by-products from gasworks. I have studied three sites in particular; this includes two English sites and one French site with Gaz de France.

The report will be as follow, I will briefly introduce the company I have been working for (Parsons Brinckerhoff), after which I will describe the production of gas from coal and the type of pollution which resulted from this process. Then I will present the studied sites and to conclude I will compare English and French methodologies for former gasworks.

For this study, many persons have collaborated. I was lucky to work with Gilles LEMOINE and Pascal JOLLY from GDF, Dominique DARMENDRAIL (BRGM), and Dominique GILBERT (MEDDE). I really appreciate the time they gave me and I thank them.

I want to thank M Russell THOMAS, M Andy LIMAGE and all the team at Parsons Brinckerhoff.

1. Parsons Brinckerhoff presentation

1.1 Part of Balfour Beatty Group

Parsons Brinckerhoff is a global consulting firm assisting public and private clients to plan, develop, operate, design, construct and maintain thousands of critical infrastructure projects around the world. They also offer resources and skills in strategic consulting, engineering, construction management, and operation, program management and maintenance. They provide services for all of infrastructure including power, community development, water, energy, transportation, mining and the environment.

The different services involving Parsons Brinckerhoff are:

Rails	Ports and marine
Roads	Generation
Airports	Transmission/distribution
Renewable	Treatment

In October 2009, Parsons Brinckerhoff was acquired by Balfour Beatty and operates as a wholly owned subsidiary of the Balfour Beatty Group. The group comprises 50,000 employees in over 80 countries (UK, USA, South Africa, Singapore...). Revenues generated in 2012 were £11b.

1.2 Environment group

The Environment Group employs 170 staff at offices across the United Kingdom located at offices in Bristol, Manchester, Godalming, London Central, Cardiff and Glasgow.
Environment Engineering is a separate business within Environment and it works across a range of sectors which include contaminated land, hydrogeology, environmental risk assessment,

remediation, waste assessment, forensic analysis and innovation. Parsons Brinckerhoff is now ranked as the largest consultancy in the UK and is also ranked as number one for staff working on overseas projects, it has about 11 684 staffs.

The following chart shows the organisation inside the UK environmental engineering group.

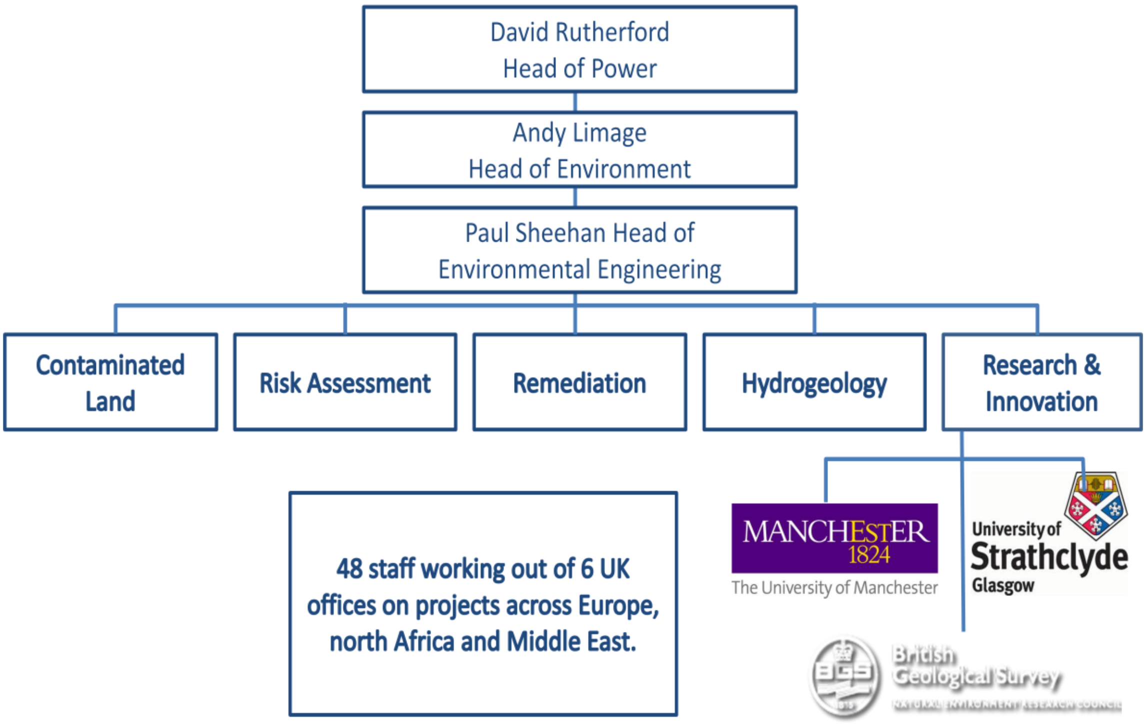


Figure 1 Chart organization of Environment Group

Several key definitions used by the Environment group and within this report are detailed below:

- <u>Contaminated land:</u> any land which appears to the local authority in whose area the land is situated to be in such a condition, by reason of substances in, on or under the land that
    - Significant harm is being caused or there is a significant possibility of such harm being caused
    - Pollution of controlled waters is being, or is likely to be caused (DEFRA, 2008)

There are three main ways in which the term “contaminated land” could be defined. It could be done according to:

- Whether contaminants are present in soil at any level
- Whether contaminants are present in soil above a given concentration. A given concentration may pose a considerably different level of risk depending on where is it, who or what may be affected, and for how long. So it would be impossible to se proportionate concentration thresholds.
- Whether contamination poses a certain level of risk.

- <u>Controlled Waters:</u> Include all groundwater, inland waters and estuaries.
- <u>Hazard</u>: A situation or biological, chemical, or physical agent that may lead to harm to or cause adverse affects. (A. Gormley, 2011)
- <u>Risk:</u> the potential consequence(s) of a hazard combined with their likelihoods/probabilities (A. Gormley, 2011)
- <u>Risk assessment:</u> the formal process of evaluating the consequence(s) of a hazard and their likelihoods/probabilities (A. Gormley, 2011)

2. Production of gas from coal

From the nineteenth century until the middle of the twentieth, thousands of gasworks manufactured gas, using coal as a feedstock. These were operated across Europe, including France and Great Britain. The implementation of natural gas brought about the close of all gasworks in the both countries. The last gasworks to be closed were in 1970 in France and in 1981 in UK.

The gasworks were decommissioned in line with the relevant guidance at the time, but this had led to the gas manufactured structures (retort house, condenser, etc…) being basically decommissioned and demolished. Those by-products and waste which remained in the soils were generally not removed to the standard required in the present day. In the case of many former gasworks sites, some traces of these by-products and wastes remain; they are either confined inside tanks or mixed with the soil. Typically by-products are ash, coke, tar, ammoniacal liquor (or water), and purifying materials (spent oxide and foul lime).

2.1 Process

The experimentation into the commercial production of gas started at the end of the Eighteenth carried out by William Murdoch (1754-1839) in Great Britain and Philippe Lebon (1767-1804) in France. Murdoch working with the engineers Boulton and Watt Company began to develop small gas plant at the beginning of the nineteenth century for lighting mill and small factories. It gave many benefits, but the main benefits to the mill and factory owners were improved safety and longer working hours. Following its demonstration at mills and factories it was then further developed by the German (1763-1830) entrepreneur Fredrick Winsor who had moved to London, realised that gas plants could be used to supply gas to small districts via gas pipes under the road. The world's first public gas company was established in 1812, to light the Cities of London and Westminster. Then the use of gas was then readily, extended through all the country and its production was increased. This existed different scales of gasworks, from small gasworks to light country houses to large gasworks to light cities and I will describe the gas making process for large town and city gasworks. Not all coals were suitable for gas making. The type of coal of preference varied owing to the primary purpose of the gas (lighting or heating). Coal was transported from the coal mines to the gasworks by ship (collier), canal barge or train. The gas was manufactured from the coal in a retort house. Within the retorts, coal was heated in an oxygen-free environment. The volatile components were driven off leaving a relatively pure form of carbon called coke as residue.

Once the gas left the retorts via ascension pipe, hydraulic main and foul main, it went into condensers. The role of condensers was to both cool the gas and also to remove coal tar and liquor from the gas, then the tar was drained to a below ground tar tank.

The next piece of equipment was referred to as the heart of the gasworks: the exhauster. It was a steam driven pump which kept the gas flowing, bringing it out the retorts. The exhauster would then push the gas through the remaining plant to the gasholders. After the exhauster the gas was first passed through the washer and then the scrubber. The tar washer would remove any remaining entrained tar. The washers and scrubbers would also remove impurities of ammonium and phenolic compounds. Once these two by-products were taken off from the gas, two other poisonous substances, hydrogen sulphide and hydrogen cyanide, were removed. When the hydrogen cyanide present in coal was passed over bog iron core (hydrated iron oxide) it would predominantly form ferric ferrocyanide also called "Prussian blue".

The gas could be purified by passing through alkaline suspensions of sodium carbonate (lime), this method was banned in the early years of the British gas industry due to the noxious odours and pollution it produced.

The purified and metered gas was stored in a gasholder for distribution later. The gasholder would act as a buffer and generally hold a gas supply of between 24 to 36 hours. The gas was distributed to various customers such as private supply, or street light.

The following drawing represents the production of gas from coal:

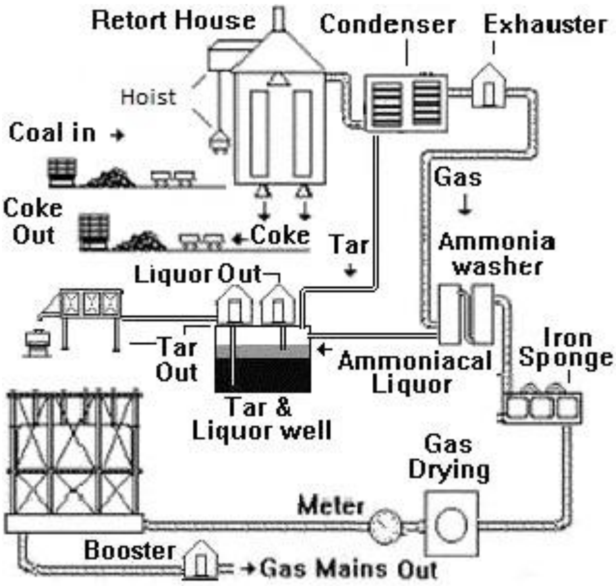


Figure 2 Production of gas from coal

The figure 2 is simplified and a specific drawing is on appendix 1 (from the Production of Gas from Coal and the Manufacture of by-products – From Extraction to Distribution produced by Dr Russell THOMAS).

2.2 Type of pollution

Words used in French are: type de traceurs.
There exist thousand of components from by-products, but some are more dangerous (carcinogenic, toxic) and are relevant of gasworks pollution.
These pollutants are:

- PAH: naphthalene, benzo(a)pyrene (the most carcinogenic) and fluoranthene
- Hydrocarbons
- BTEX (benzene)
- Cyanide (ferric ferrocyanide)

They were identified by the US EPA services and used as a reference because they are the most frequently occurring on the former gasworks, they are regarded as very hazardous, and their physicochemical characteristics (solubility, mobility) influence the fate of compounds inside the environment.

The type of remediation depends on the pollution, sometimes the pollution can't be removed completely, and the investigators have to consider a limit value of exposure. For example, if an underground storage tank (UST) has leaked and coal tar has spread into the ground and the groundwater, the plume can be treated but if the substratum has been impacted the cost will be so expensive that the contamination will have to remain on on-site. Therefore in France the maximal

plume allowed under the contaminated source is 500m, it takes account the mobility of the components which is very low.
For each rehabilitation of former gasworks two environmental aims are distinguished:

- Verify that the media is compatible to the permanent use (in France is called démarche d'interprétation de l'état des milieux)
- Adapt the site state or the use whether to decontaminate the site or achieve a better land use (plan de gestion)

Usually the polluted soils are excavated and must be considered before works, the transfer of liability is then between the site owner and the landfill operator. In both countries, this is a key point and need to be dealt with by the site owner.

3. Case studies

To realize this subject, I investigated and undertook the study of two sites. On the first site, contamination was generated by polluted ground on a former gasworks. The second site is polluted by a leachate of by-product of iron manufacture.

3.1 SEREBAR system

3.1.1 Site description

The site was a former gasworks, the gas making activities started in 1840 and continued until production was ceased in 1971. The site consisted of four gasholders and a horizontal retort house. The gasworks was the last in the South-West of England to produce coal gas and stopped production in 1971.
The site lies on 3.4 hectares and comprises offices, car parks, a waste tank and an electrical substation. Two decommissioned gasholders form part of the Wales & West Utilities Ltd property (Gas Company) are also within the site.
Parsons Brinckerhoff has been involved in this project since 2000 and the site was investigated since 2001. The main source of pollution is located on the North-West of the site as is shown in Appendix 2 in red line. In the 19th century, this zone comprised a coal store, an oil gas plant and a retort house. As explained previously the retort house was the place where the gas was manufactured by heating coal in retorts in the absence of air. The soil became polluted due to spillages and potential leakages from underground pipes and tanks. The main contaminants found from the former manufactured gas plant were polycyclic aromatic hydrocarbon (PAH) and benzene, ethylbenzene and xylene (BTEX). The soil and the groundwater have been affected by the pollution. Therefore Parsons Brinckerhoff developed a groundwater treatment system with Queen University Belfast, referred to as the Sequential Reactive Barrier (SEREBAR). The soil cannot be treated as buildings and gasholders are in place. SEREBAR system has been working since 2004, however some problems have occurred on-site, these have included such as an unexpected high concentration of cyanide appearing in the groundwater and vandalism acts. That reduced the effectiveness of the system and included some changes inside the process to take account the concentration of cyanide.

The main goals of this study are to treat and to monitor the groundwater. My mission is not over as the concentrations inside the groundwater are still higher than the target values (EA Remedial Action Values). The system is still being re-commissioned following vandalism. Firstly I will describe the geology of the site, then I will present SEREBAR system and I will conclude on positive impacts of the process.

3.1.2 Geology and Hydrogeology

The geology of the site contains, Made Ground comprised a variety of different type of soils. The soil encountered ranged from sandy, silts to gravels with fragments of brick, tarmac, concrete, glass, coke, clinker, coal, asbestos and metal waste. The thickness of this layer across the site varied from 0.9m to 3.4m

The natural ground overlain the Made Ground comprised of alluvial clay, silt and sand (Quaternary alluvial deposits). Its thickness is typically to 2.5m at 4.6m.

This layer is underlain by bedrock of Permian breccio-conglomerates, sandstones with subordinate mudstone and occasionally with argillaceous and/or calcareous matrix. Due to the low permeability of the weathered breccias, the underlying bedrocks limits vertical hydraulic interaction and the overlying alluvial sediments can be regarded as a single unconfined layer.

Groundwater beneath the site moves in a southerly direction in the Alluvium, suggesting that the marina situated to the North of the site may be acting as a recharge source. The underlying impermeable breccia is assumed to be an aquitard. Monitoring of the water table shows a typical seasonal pattern, with recharge being recorded in winter months (between October and February).

Previous investigations undertaken at the site have identified the following hydrogeological conditions:

• Groundwater level	3.5m BGL
• Hydraulic Gradient	Very shallow gradient flowing approximately North to South, with seasonal variations.
• Hydraulic conductivity value of Gravels	1m/d
• Effective Porosity	Conservative estimate of 27% for the gravel aquifer.

The canal passes along the North eastern boundary of the site running parallel to the River (North). The canal forms a relatively impermeable barrier between the river and the site. This unexpected regime suggests that the canal may act as a hydraulic boundary.

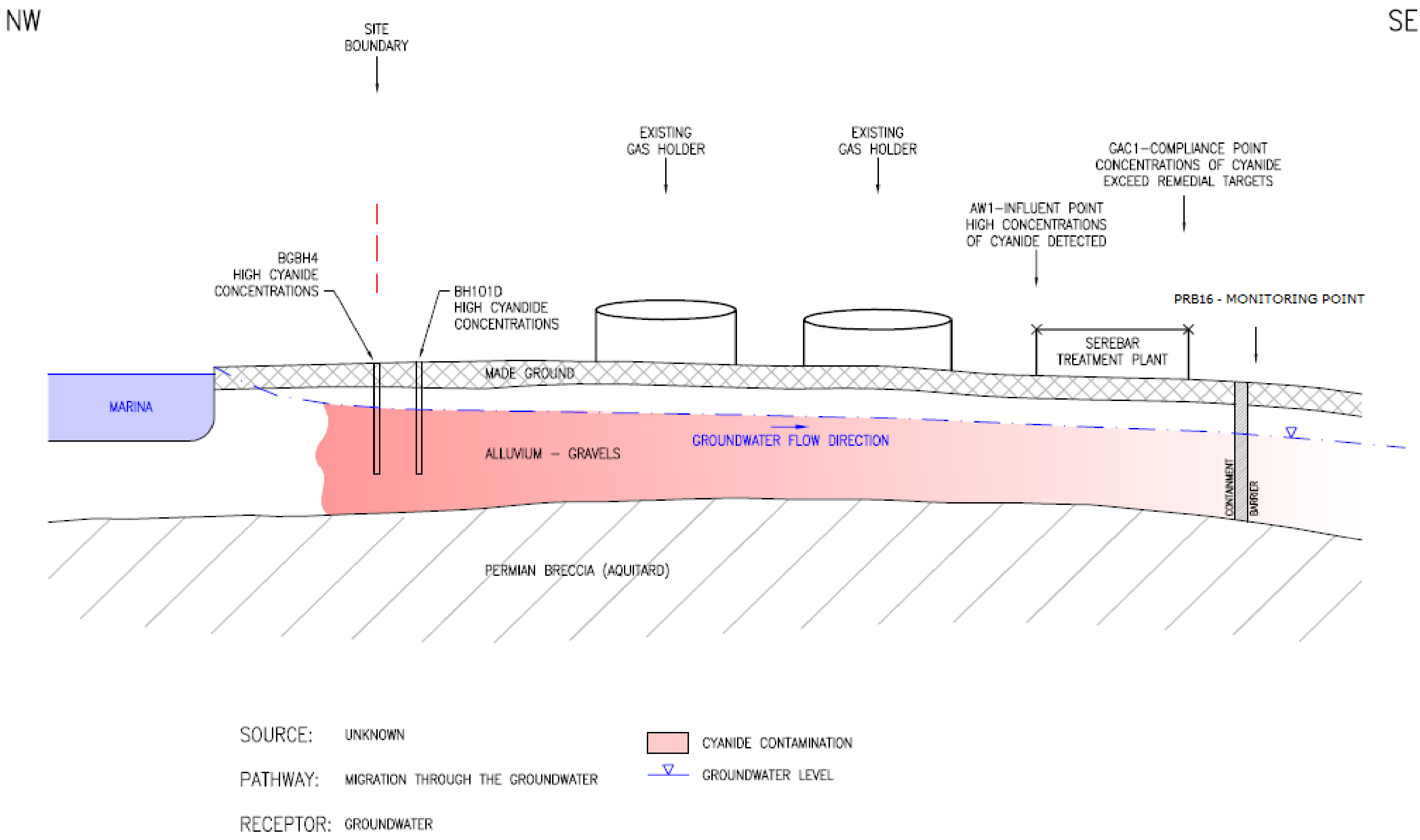


Figure 3 Plan of the site

The previous drawing (figure 3) illustrates the previous explanations and shows the concentration of cyanide inside the groundwater.

The site is within a floodplain area of the River, although there are flood fences in place along this section of the River. The Environment Agency website indicates that the site is located in an area with a moderate chance of flooding.
The geological and hydrogeological contexts are known, the system can be defined.

3.1.3 SEREBAR process

The purpose of Sequential Reactive Barrier (SEREBAR) system is to remediate groundwater polluted with by-product of the gas-making process. The main contaminants from former manufactured gas plant are polycyclic aromatic hydrocarbon (PAH), benzene, toluene ethylbenzene and xylene (BTEX).

Usually, at the rear of SEREBAR system two permeable reactor barriers (PRB) are installed. They act to deflect groundwater into the treatment gate of the system. PRB offers two main configurations;

Continuous PRB: an excavated trench backfill with the reactive materials (most commonly used material is Zero Valent Iron)

Funnel and gate PRB: employs low permeability cut-off walls (funnels) to direct groundwater towards the high permeability reactive zone (gate).

The actual design of the remediation system comprises one interceptor and six steel chambers.

The interceptor is designed to remove non aqueous phase liquid (NAPL) from the treatment canisters, NAPLs will be separated from groundwater through differences in density. First and second chambers (S0 and S1) promote anaerobic biodegradation of site groundwater. They contain sand. Chambers 2 and 3 (S2 and S3) with air sparging promote aerobic biodegradation of groundwater, they also are full of sand. During the first zone, further degradation of compounds have not been removed, consequently a sufficient amount of oxygen permit to achieve the efficient biodegradation of organic compounds. The two latter canisters (GAC1 and GAC2) contain Granular Activated Carbon and act as powerful sorbent for any organic compounds remain. The presence of the GAC treatment step (sorption) provides a final safety net for the removal of any undegraded compounds and prior to effluent discharge.
A well is located in up gradient of the treatment gate to allow pumping of water into the system and permit sufficient capture of the plume. The flow rate is 2.0 m^3/d.

The figure below presents the SEREBAR system

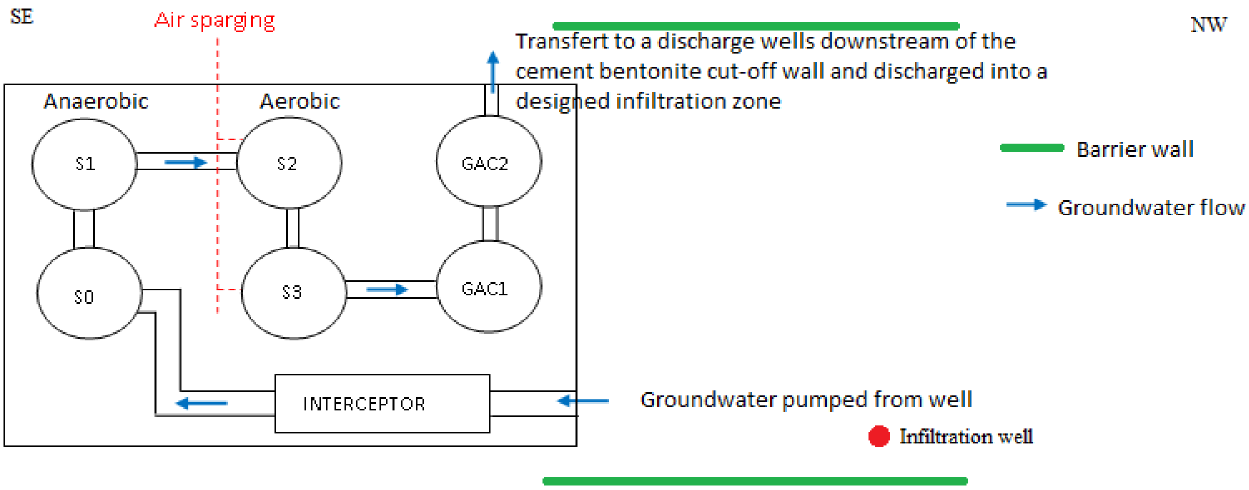


Figure 4 Conceptual model of SEREBAR system

SERBAR system is able to operate under passive (installed beneath water table) or semi-passive (installed underground but abode the water table) groundwater flow condition.

3.1.4 Contaminants treated by the system

SEREBAR system has been established to attract the following chemicals:

PAH: Polycyclic Aromatic Hydrocarbon
BTEX: Benzene, Toluene, Ethylbenzene and Xylene
NAPL: Non-Aqueous Phase Liquid
TOC: Total Organic Carbon
TPH: Total Petroleum Hydrocarbon, and
Heavy Metals (As, Pb, Cu, Ni, Zn, Fe, Se, Cd, Cr and Hg).

DNAPL such as PAH run along the joints of the porous media as Breccia and the plume of DNAPL is very low in the groundwater. That’s why the groundwater treatment is so long.
All concentrations of the identified contaminants of concern are required to fall below the EA Remedial Action Values. The table 1 below represents an example of the last laboratory results against the target values.

Table 1 Concentrations screening against Remedial Action Values

		AW1 Water 19/06/13	GAC1 Water 19/06/13	PRB16 Water 19/06/13
Contaminants	**EA Action Value (µg/l)**	Input	Treatment	Output
Total Cyanide Low Level	143	239	1770	96.6
Naphthalene	15 to 60.6	64	<1	0.149
Phenanthrene	12.2	17	<0.022	0.044
Pyrene	11.4	19.8	<0.015	0.85
Benzene	66 to 749	<1	<1	<1
Toluene	176 to 12,100	<1	<	<1
Ethylbenzene	49.8 to 182	<1	<1	<1
o-Xylene	66 to 749	5.83	<1	<1
Chrysene	0.7[A]	1.09	<0.013	0.021
Phenol	30[B]	1.2	<5	<5

[A] Lowest Effect Concentration taken from Polycyclic Aromatic Hydrocarbons (PAH): Priorities for Environmental Quality Standard Development, R&D Technical Report P45, Environment Agency, 2001, M J Grimwood

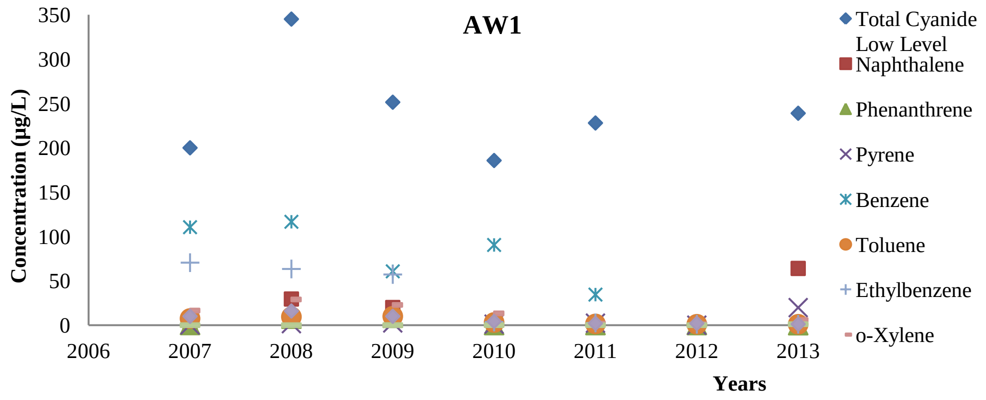
[B] Environmental Quality Standard Annual Average

The comparison between the contaminants concentrations entering and going out of SEREABAR system shows the benefice of this treatment. The values have been divided by two to hundred.
After the biological treatment the water is released into the sewers. The attracted DNAPL's are collected and they will be sent to chemical companies.

3.1.5 Relevant Results

Since SEREBAR system has been operational, the concentration of cyanide in groundwater increased, this fact was unexpected. The cyanide can be found in purifiers, it is the main source on gasworks, located beyond the boundaries of the current site (off-site). As such, cyanide removal system was never incorporated into the system. The concentration seemed higher than those observed in the original investigation.

The graph (figure 5) below presents a glance of the evolution of PAH, BTEX, Cyanide into the groundwater over six years. The data came from the groundwater survey on up gradient borehole (before the water enters into the system) AW1, inside the system GAC1 and PRB16 (the monitoring point at the southern end of the impermeable barrier wall).



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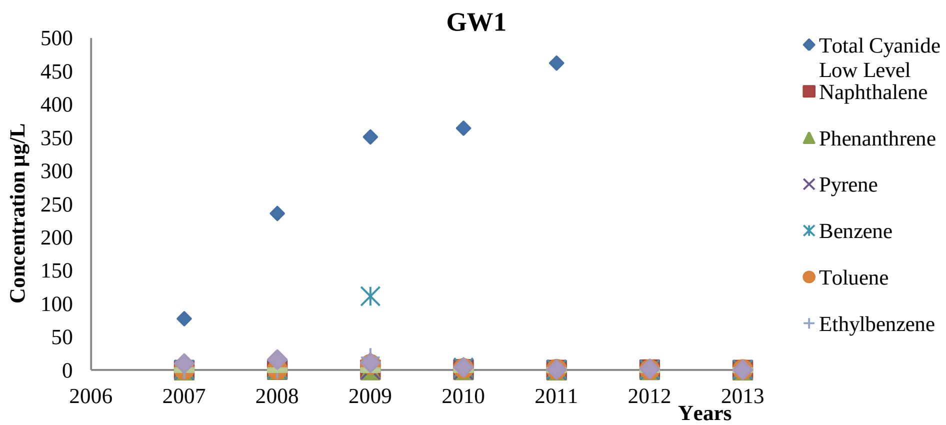

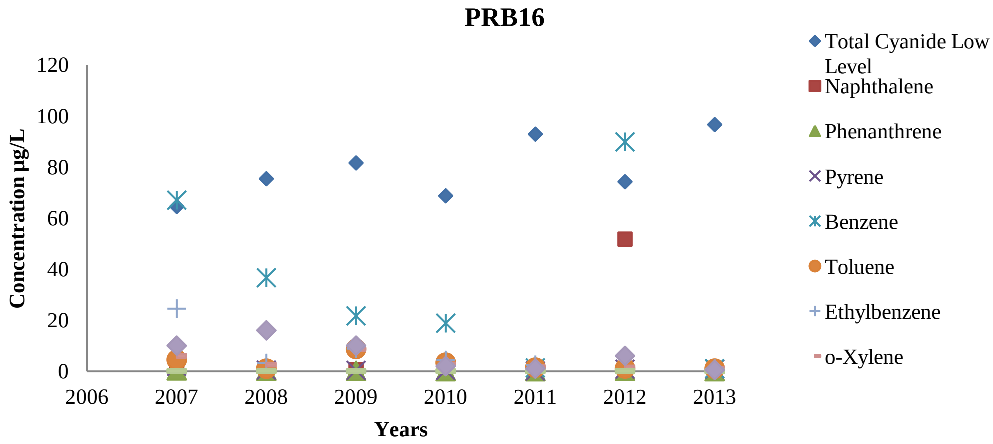

Figure 5 Concentration over 6 years

The extraction of groundwater produced a quantity of cyanide that was below the limit of detection in two samples AW1 and GW1 in 2012.

Following almost 6 years of successful operation of the SERABAR system (since the beginning of the treatment), the chemical analysis data obtained from monthly monitoring indicates a gradually increasing trend of groundwater contamination entering the system, suggesting that the barrier walls have been capturing the contaminant plume. However the high concentration of cyanide did not decrease. Samples in 2008 demonstrated an increase in the influent concentration of cyanide entering the SEREBAR system (AW1). Unfortunately, the biological treatment system has since been unable to treat the cyanide and this has the resulted in consistent failures to meet the EA Remedial Action Values of 143 µg/L. Numerous site investigations has been realized to improve the system to treat the elevated concentration of cyanide. These concentrations have a negative impact on the system: microorganisms, particularly those acclimatized to anaerobic conditions (such as the microbial communities in S0 and S1, see figure 4) can be sensitive to high cyanide concentrations in their environment. Should the elevated concentrations of cyanide continue, there is therefore the potential for microorganisms within the SEREBAR system to be negatively affected, leading to reduced performance at treating organic contaminants. Investigations and researches have been realized to find potential options to improve the performance of SEREBAR such as replace the contents of S0 by Zero Valent Iron.

The two last years the site was vandalized and the system had been length of time out of operation. In 2013, after the system has been repaired the groundwater monitoring was able to restart. Many times I have been on-site to sample the groundwater. On-site, odor of products was emerged from

sample S1. The source of the odor was not sure; this may due to the stop of SEREBAR. The sampling has been realized for five chambers, one interceptor (AW1) and the well PRB16.
The obtained results in table 1 show the positive impact of the groundwater treatment. The contaminant concentrations entering in AW1 are higher than the EA Remedial Action Values, but once they have been treated by the process these concentrations are below (results at PRB16).

3.1.6 Conclusion

This study shows the opportunity of former gasworks rehabilitation. Although the removal of facilities and tanks the environmental investigations have revealed occur of pollution on the ground and the groundwater. However the site has been adapted with its use. An innovative project has been created in order to treat biologically the groundwater. This process has been successful, almost the concentrations of concerned contaminants are below the EA Remedial Action Values. However the concentration of cyanide still needs to be monitored.

3.2 Potential Pollution from Blast Furnace Slag

3.2.1 Site Presentation

Parsons Brinckerhoff were commissioned to undertake an environmental risk assessment of potential pollution from Blast Furnace Slag in Northern England.
The Windfarm project (the site) has involved the use of Blast Furnace Slag (BFS) as a sustainable alternative to quarried aggregate for the construction of roadways and initially in the construction of piling platforms. On the following figure the green and pink roadways represent those constructed with BFS. The site comprises an area of relatively level arable land divided by numerous drainage ditches.
(Thomas, Scoping Report: Pollution from Blast Furnace Slag at Northern England, 2013).
Before the land received a manufacturing gas plant, all the facilities have been removed, no tank or pipe remained on-site. This site was rehabilitated to build a wind farm, with about thirty turbines.

During the winter 2013 heavy rainfall had led to the formation of standing water in isolated areas. On site a green/yellow discoloration of the water had been noticed. Three locations had been identified in the southern site part (orange on the figure 6). The water discolouration was due to leachate from BFS.

The Environment Agency was informed of the pollution, and the site needed to be investigated.

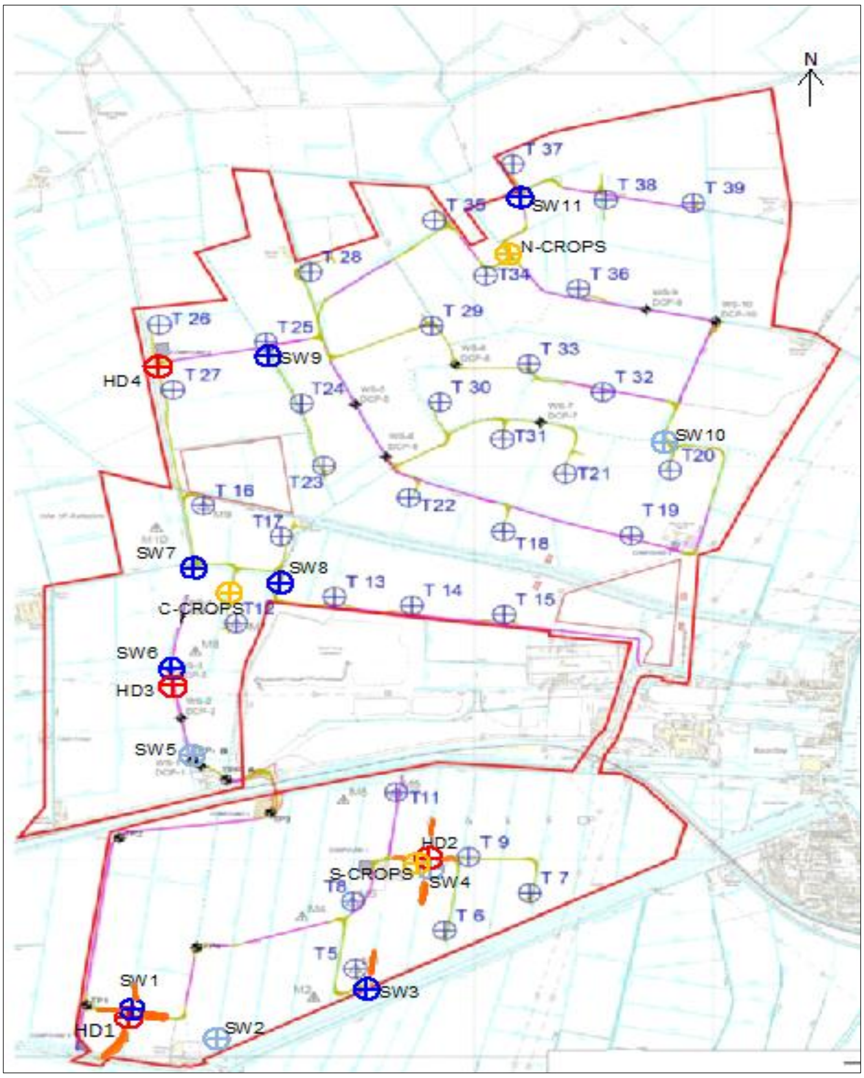

Figure 6 Site plan

The principle objective of the current study is to provide an environmental support for the long term management of the problem associated with the use of Blast Furnace Slag. This is included the following steps:

- To undertake sampling and chemical analysis of soils and crops located close to the engineering roadways, surface water from drain situated in sensitive areas then BFS from selected site roadways
- To test the leachability on site-won BFS to inform the source term in future risk assessments
- To produce a conceptual site model, based upon the finding of the study and the chemical analysis, and
- To identify a requirement for further investigation risk assessment (Human Health and Controlled waters)

I undertook all the steps expected the Human Health assessment. However at the end of my work experience all laboratory results were not delivered, so I'm not able to provide all the results. This study is not finished so I will give the best relevant findings.

3.2.2 Geology and Hydrogeology

The site comprises an area of relatively level arable land divided by numerous drainage ditches, including a major drain crossing west-east.

The geology of the site based on Final Geotechnical report Ground Investigation 2009 (Geotechnical, 2009) is mainly.

- Topsoil: is black slightly clayey sand with roots. Its thickness is around 0.3m.

- Made ground; is predominantly sand, but may have been derived in part from the underlying natural sand and in some places the boundary between two is indistinct. This layer is between 0.2 to 1.62m.

Superficial deposits of the site are alluvium, sand, clay and peat. The layer lies between 2.5m to 13.8m. Different types of sand can be encountered, from British Geological Survey (Survey, 2013). Clays have a low to intermediate plasticity. The plasticity within the peat is extremely high indicating a high volume change potential.
Bedrock present only on one borehole, located on the West, is Mercia mudstone Group. There is a very weak mudstone with many gypsum bands and also weathered to firm clay, its thickness is approximately 1.2m.
The superficial deposits (of alluvium, sand, clay and peat) are designated Secondary A status and the bedrock (Mercia mudstone) are designated Secondary B status beneath the entire site.

The groundwater is mainly encountered as seepage within the sand, and unconfined. In three ground investigation reports the depth of the groundwater lies between 0.3m to 3.5m BGM. Based on the figure 6, we can quickly define the characteristics of the aquifer. The site is surrounded by plenty of drainage ditches, and the topography of the site is very flat. Moreover, the permeability (K) is low (mainly alluvium-silt and peat) and is about $2.3\ 10^{-6}$ m/s.
The hydraulic gradient is deduced from literature. Table 2 gives a range of hydraulic conductivities of natural soils encountered at Windfarm Project. These values come from ‘Construction Dewatering and Groundwater Control’ J.P Powers *et al*., 2007.

Table 2 Range of hydraulic conductivities encountered on the site

Soil type	Hydraulic conductivity range (m/s)	Hydraulic conductivity description
Clay	1.10^{-10} to 1.10^{-7}	Very low to practically impermeable
Silt	5.10^{-7} to 1.10^{-6}	Very low
Peat	1.10^{-5}	Low
Silty sand	1.10^{-5} to 5.10^{-5}	Low

In accordance with the literature, the hydraulic conductivity of the site, doing a geomean is approximately $H=1.10^{-6}$ m/s.

Then the Darcy law is applied:

$$v = K\frac{dh}{L}$$

With dh: difference heads between a main drain and a main river, around 5m
L: distance between a drain and a river, around 600m

$$v = 5.75\ 10^{-9}\ m/s$$

The groundwater flow is therefore mainly nonexistent which involves an absence of the circulation of the oxygen (anaerobic condition). The groundwater flow is governed by the motions of the tides (river along the site). Groundwater is controlled by site drainage therefore groundwater levels are linked to standing water levels in drainage ditches at the site.
The alluvium deposit is made of fine to coarse grains, and relatively homogenous. The effective porosity (w), provided by Brady and Kunkel paper, is 26% (Appendix 3).

Briefly the transfer time can be estimated as very slow as the convective flow (U) is around

$$U = 2.21\ 10^{-8}\ m/s$$

This is not surprising to find a weak transfer time as the site is very flat and clay-silt are dominant.
The groundwater vulnerability is designated as Minor Aquifer Intermediate, but it does lie within a source protection source.

The whole site area is classified by the EA as being at risk of flooding from rivers or the sea. (Agency, 2013)

3.2.3 Blast Furnace Slag definition

Blast Furnace Slag (BFS) is an industrial by-product of iron produced in blast furnaces with the ingredients, limestone, iron ore (Fe_2O_3, or Fe_3O_4) and coke. BFS consists of silicates and aluminosilicates of calcium and magnesium together with other compounds of sulphur, iron, manganese and others trace elements. The chemical analysis of the BFS for the site is presented in table 3.

Table 3 Composition of Blast Furnace Slag on-site

Component	Concentration (%)
Iron oxide	32.72
Calcium oxide	40.84
Silicon oxide	13.27
Magnesium oxide	5.24
Aluminium oxide	1.37
Phosphorous oxide	1.51
Manganese oxide	4.27
Titanium oxide	0.57
Sulphur oxide	0.20
Potassium oxide	0.02
Sodium oxide	0.03
Chromium oxide	0.11
Barium oxide	0.02
Vanadium oxide	0.30

BFS contains also metals, such as lead or arsenic.
Parsons Brinckerhoff has undertaken in July 2013 works on BFS, in 4 different locations including fresh BFS (recently on-site). The characteristics are:

- pH value of between: 9.5 and 10.4
- total sulphate of between 1.00% and 2.03%
- total sulphur of 0.44% and 0.60%

- water soluble sulphate of between 21 mg/L to 1540 mg/L
- sulphide of between 4.3 mg/kg to 67.9 mg/kg

The results are almost similar to previous results undertaken in March by Parsons Brinckerhoff. Excepted for the water soluble sulphate, the values are higher than in March. This can be explained by the sampling of surface water undertaken in stagnant water and in March the water sampling have been done slowly after heavy rainfall. The ditches are drier in summer so the chemicals inside the water are concentrated in some points.

The BFS is commonly utilised as a construction materials in roads, fills and embankment. To give an idea of BFS in appendix.3, some pictures represent various forms of this by-product.

3.2.4 Site Works

The study was divided in many steps: leaching tests researches, sampling of the site, analysis and screening results against standard values.

I undertook researches concerning the leachability tests. The purpose of these tests is to evaluate the behaviour of the Blast Furnace Slag under wetting and drying conditions, and also for a long-term. Two leaching tests have been chosen:

BS EN 12457-2:2002 “Characterisation of waste, compliance test for leaching of granular waste materials and sludges”.

BS EN 1744-3:2002 “Tests for chemical properties of aggregates” the test is designed to replicate the aggregates in, or close to, the state they would be used in a hydraulically bound material. This test is reasonably new to the UK.

Each test wad repeated about 10 times to gain an understanding of the decreasing source term.

Once the laboratory results received, the purpose is to obtain a risk assessment and to study the impact or not of the leachate of BFS on the groundwater and the surface water. The leaching test results will be compared with thresholds for the acceptance of wastes into landfill.

This work of research was interesting because these kind of tests is rarely used in the UK, and I was able to use reports with similar experiences made in the USA and in Sweden (Lidelöw, 2011) (WRAP, 2007).

Following this, with an engineer we went on-site to sample the surface water, crops, soil close to the crops and the BFS. The previous figure (Figure 6) shows the location of sampling.

The surface water sampling has been established all around the site, included the three contaminated zones. In the South almost the drainage ditches were dry or contained standing water. The results from standing water should consider with caution. On the map they are called SW1 to SW11. It’s recorded in various references (Association, 2003), that in situation where the BFS is placed in areas with stagnant or slow moving water, the leachate from BFS may be discoloured (characteristic yellow/green) and have a sulphur odour. This is exactly the observation at the affected areas at the Windfarm Project, in winter. Also calcium silicates (within unbound BFS) such as akermanite are known to slowly release hydroxyl ions, when in contact with perched groundwater, and initially increase the pH value. This was observed in a drain. But this effect diminished after dilution on the following days. The contaminated water was removed either by pumping to a tanker or excavating the impacted zone. On the contaminated zones, Blast Furnace Slag is not in contact with perched groundwater and has been sub-based. At these zones, we sampled the surface water when it was possible. On the day of investigation, no discoloration of the surface water has been observed.

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Concerning the Blast Furnace Slag only four locations have been gathered. The point HD4 represents the fresh BFS, this compound was recently on-site. The BFS samplings will be analyzed for the leaching tests and for chemical.
The crops must be close to a ditch and an engineering roadway (approximately 10m), consequently the choice of the sampling has been realized on-site. If there is a gap or a layer of mud next to the field we consider that the leachate from BFS is stopped. The groundwater or the surface water can't be contaminated, the leachate is diluted. The samplings (crops and soils) have been taken in four locations for each point at 1m, 2m, 5m, and 10m.
The sampling of the site has been undertaken over two days using the recommended PPE (Personal Protective Equipment) and following the Health and Safety Plan and the Environmental Plan. Those plans are mandatory.

Investigation and work sites have been based on many guidelines like EA document CLR11 'Model Procedures for the Management of Contaminated Land'. This guidance is applied for both groundwater and soil.
Only the controlled water risk assessment is going to be studied, the environmental plan has been realized for the Windfarm Project, but this is not explained in this report.

3.2.5 Potential Risks to ground and surface water

Since the site visit, on the 26th March 2013 done by Dr THOMAS, no further pollution incidents have been noticed, but it should noted that rainfall has been very limited over this period. Should significant rainfall occur as it did at the beginning of 2013, saturating the ground, the potential remains for the characteristic yellow leachate to form and potentially pollute the groundwater. It's therefore recommended that the risk to ground and surface water are modelled. Tool used will be PB Controlled Water Risk Assessment Tool. This worksheet can be used to determine remedial target for soils and/or for groundwater. This is an optimization from P20 Remedial Target worksheet (from EA), the mistakes are minimized.
The potential polluted linkage defines the potential source, the pathways and the receptors.

Potential source:

The main potential source is the Blast Furnace Slag. The leachate produced has the capacity to be toxic due to the alkalinity and its ability to deplete oxygen. Researches have demonstrated that after repeated leach tests the only metals with elevated concentration remaining in the BFS were aluminium, barium, iron and manganese. These concentrations did not diminish appreciably from repeated leaching test carried out on the BFS.

Potential Controlled Water Receptors

Based on the above, the following potential controlled water receptors have been identified:

- Groundwater: Alluvium deposit: Secondary A Aquifer
  Mercia Mudstone Group: Secondary B Aquifer
- Surface Water: Main rivers (four rivers) close to the project and main drains.
  .

Potential Pathways

The potential pathways have been summarised as follow:

- Infiltration through the BFS to the granular made ground or sand until the groundwater reached, then horizontal transfer into the made ground to the surface water feature.
- Infiltration through the BFS to the cohesive soil such as clayey silt until the groundwater reached, then horizontal transfer into the clay to the surface water feature. (Lavaud, 2013)

The following figure 7 shows the potential polluted linkage, this is a kind of conceptual site model. This is a simplify version.

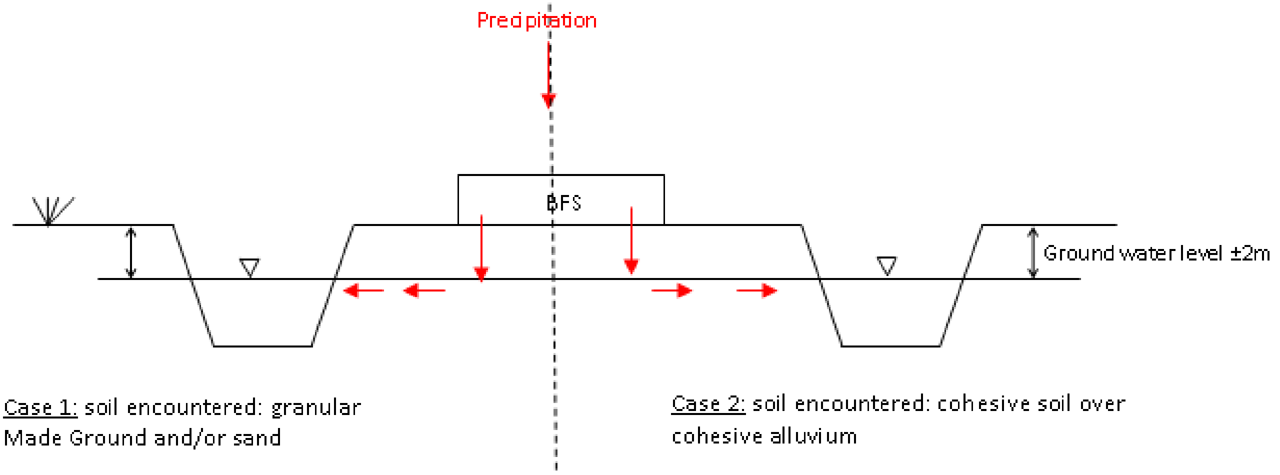

Figure 7 Simplify drawing of the potential polluted linkage

The case 1 is the worst because the capillary action is less important contrary to the case 2. In the cohesive soil the suction is more obvious, the leachate from BFS slow. In appendix 4, the official conceptual site model has taken account all receptors this is included crops.

The results of the analytical testing for field soils and the BFS have been screened against appropriate generic assessment criteria (GAC). All the details of laboratory analysis and screening of water/solid sample are provided in the Table 4.
Generic assessment criteria have been selected with reference to the principal receptors, ditches, rivers and groundwater. Therefore UK DWS (Drinking Water Standards) and Environmental Quality Standards (EQS) for the protection of surface water quality (Water Framework Directive) have been adopted as the appropriate water quality standards (WQS). Certain EQS values have been adjusted according to water hardness and have been selected from inlands or Coastal or Saline criteria. The most stringent relevant quality standard has been utilised where both drinking water standards and EQS exist.

The following table summarizes the screening assessment.

Table 4 Summary of exceedances of Generic Assessment Criteria

Determinant	GAC mg/l	GAC reference	BFS Leachate		Surface Water	
			Maximum Concentration mg/l	No of exceedances	Maximum Concentration mg/l	No of exceedances
Aluminium	0.2	DWS	0.7	2	0.084	0
Ammonium	0.04	EQS	0.1	0	3.6	7
Arsenic	0.01	DWS	0.005	0	0.005	0
Barium	0.1	DWS	0.128	1	0.293	6
Cadmium	0.00008	EQS	0.001	3	0.001	7
Chloride	250	DWS	5	0	343	1
Chromium	0.032	EQS	0.005	0	0.005	0
Copper	0.04	EQS	0.005	0	0.005	0
Iron	0.2	DWS	0.326	2	0.484	1
Lead	0.0072	EQS	0.002	1	0.001	0
Manganese	0.05	DWS	0.171	3	0.910	7

Mercury	0.0003	EQS	0.0001	0	0.0001	0
Molybdenum	0.07	DWS	0.005	0	0.518	1
Nickel	0.15	EQS	0.001	0	0.005	0
Selenium	0.01	EQS	0.005	0	0.005	0
Sulphate	250	DWS	8	0	931	6
Vanadium	0.02	EQS	0.044	1	0.005	0
Zinc	0.05	EQS	0.008	0	0.02	0

Then the laboratory results were utilised inside the EA remedial target worksheet (called also P20). P20 worksheet was used to carry out this hydrogeological risk assessment. The input parameters utilised in the model for the site are summarised in Table 1 in appendix 5.

The selected parameters were based on site specific data, or in the absence of such, conservative but realistic assumptions.
The rainfall recorded at the station Auckley (the closest River) is 608mm per year. The value used in the model is 50% of the infiltration equal to 8.3E-04 m/d.
The hydraulic gradient has been calculated from approximate distances. The distance between the main River and the middle of the site is almost 2300m and the difference between the elevation heads is approximately 3.40m.

Model Results
The adopted site specific risk assessment criteria (SSRA) for soils (BFS and Field soil) and groundwater are summarised in Tables 5 and 6 below. This derived SSRA are based on the standard outputs of the Environment Agency model.

Case 1: Comparisons between the BFS and the soil Uncalibrated (comparison 1) and the field soil and the soil Uncalibrated (comparison 2) assess the risk posed by the use of the material BFS.
Nine contaminants are exceeded in comparison 1, and ten contaminants in comparison 2.

Case 2: The scenario 2 compares the groundwater against the field soil and BFS.
The number of exceedances for the groundwater against the field soil or BFS is five.

Table 5 Case 1 Adopted SSRA Soil

Determinant	Target groundwater µg/L	BFS (uncalibrated) mg/kg	Exceedance	Field soil (uncalibrated) mg/kg	Exceedance
Aluminium	3.10E+02	6.30E+02	Yes	7.65E+02	Yes
Ammonium	6.20E+01	7.55E+02	No	9.17E+02	No
Arsenic	###	2.11E+188	No	7.15E+143	No
Barium	1.55E+02	8.62E+00	Yes	1.05E+01	Yes
Cadmium	1.26E+115	2.30E+56	No	2.22E+42	No
Chloride	3.88E+05	5.25E+04	No	6.38E+04	No
Chromium	4.96E+01	1.28E+00	Yes	1.56E+00	Yes
Copper	6.20E+01	2.94E+00	Yes	3.57E+00	Yes
Iron	3.10E+02	1.05E+01	Yes	1.28E+01	Yes
Lead	1.12E+01	1.36E+01	Yes	1.65E+01	Yes
Manganese	4.17E+133	1.35E+67	No	1.72E+51	No
Mercury	4.65E-01	3.28E-02	Yes	3.99E-02	Yes
Molybdenum	1.09E+02	2.95E+00	Yes	3.58E+00	Yes
Nickel	2.33E+02	2.05E+01	No	2.49E+01	Yes

Selenium	1.55E+01	1.06E-01	Yes	1.29E-01	Yes
Sulphate	3.88E+05	5.25E+04	No	6.38E+04	No
Vanadium	1.22E+231	8.50E+116	No	2.19E+89	No
Zinc	8.13E+147	2.57E+74	No	6.42E+56	No

Table 6 Case 2 Adopted SSRA groundwater

Determinant	Target groundwater µg/L	BFS (Groundwater) mg/L	Exceedance	Field soil (Groundwater) mg/L	Exceedance
Aluminium	3.10E+02	3.10E-01	No	3.10E-01	No
Ammonium	6.20E+01	6.20e-02	Yes	6.20E-02	Yes
Arsenic	###	####	No	####	No
Barium	1.55E+02	1.55E-01	Yes	1.55E-01	Yes
Cadmium	1.26E+115	1.26E+112	No	1.26E+112	No
Chloride	3.88E+05	3.88E+02	No	3.88E+02	No
Chromium	4.96E+01	4.96E-02	No	4.96E-02	No
Copper	6.20E+01	6.20E-02	No	6.20E-02	No
Iron	3.10E+02	3.10E-01	Yes	3.10E-01	Yes
Lead	1.12E+01	1.12E-02	No	1.12E-02	No
Manganese	4.17E+133	4.17E+130	No	4.17E+130	No
Mercury	4.65E-01	4.65E-04	No	4.65E-004	No
Molybdenum	1.09E+02	1.09E-01	Yes	1.09E-01	Yes
Nickel	2.33E+02	2.33e-01	No	2.33E-01	No
Selenium	1.55E+01	1.55E-02	No	1.55E-02	No
Sulphate	3.88E+05	3.88E+02	Yes	3.88E+02	Yes
Vanadium	1.22E+231	1.22E+228	No	1.22E+228	No
Zinc	8.13E+147	8.13E+144	No	8.13E+144	No

means that the value is very low
Cells shaded red indicate that the concentration exceeds the calculated SSAC

3.2.6 Summary

Groundwater and surface water features have been selected as the principal receptors, therefore relevant UK DWS and EQS were chosen for generic assessment criteria (GAC).

Comparison between surface water to GAC indicates that the quality of the water features is not good. Almost one in two determinants exceeds the selected GAC: Ammonium, Barium, Cadmium, Chloride, Iron, Manganese, Molybdenum and Sulphate. Ammonium, Cadmium and Manganese are in exceedances for all surface water samples. But these results should be considered with caution as the sampling of the surface water has been made in stagnant water. The final results are summarized in table 4 appendix 6. The same experience has been done for the sample SW3 (one of the main drain) and the results are not similar only the concentration of ammonium exceeds. Moreover elevated ammonium concentration is not harmful for the groundwater.

The results from the two leaching tests are confidential and relevant. They show that as the three samples have been leached many times, the contaminant concentration reduced. Consequently for key contaminants like sulphate they leached out quickly, nevertheless alkalinity was much slowly at decreasing. This phenomenon is due to as limestone is one of the three major constituents of iron manufacture; it is present in large quantities and more thoroughly bound into BFS than the others elements.

Another good point, the results show that there are no sign of any toxic heavy metals leaching.

To date, with the relevant results, the use of Blast Furnace Slag at the Windfarm Project is not an issue for the groundwater.
Some analysis have been done on crops but to date, I'm not able to give the laboratory results.

3.2.7 Conclusion

The detected discoloration of the surface water following heavy rainfall came from the leachate of BFS. This anomaly was found in only three zones and has been removed. The water has been sent to a water treatment plant. The use of BFS on-site has been reconsidered and investigations have been undertaken. In order to assess the impact from the leachate of BFS on the groundwater, leaching tests have been realised as well as site works.
The site results are able to demonstrate that the use of BFS does not affect the groundwater in a long term. The elevated concentrations from the leachate are dissolved days later, so the discoloration was an aesthetic issue.

4. Comparison of French and English methodologies

The comparison of both methodologies will be the observation of scientific practices of underlying principles and research methods used. This is based on approaches, tools, and references used in the United of Kingdom and in France.

The rehabilitation of former gasworks illustrates this comparison. Once the site was no longer required for gas manufacture, the gas plants were sold, the buildings demolished and the site rehabilitated, but sometimes by-products and/or wastes were not removed to the standard required. In France the awareness to remediate former gasworks was happened in 1992, following an unanticipated pollution from UST. GDF has then identifies all former gasworks. In Great Britain, former manufacturing gas plants are considered as heritage and their locations are known. We consider that the former gasworks as a contaminated land.

The government policies on contaminated land are similar in both countries, they have the same objectives, which are:

- To identify and remove unacceptable risks to human health (controlled waters, soils)
- To seek to ensure the contaminated land is made suitable for its current or future use
- To ensure that the burdens faced by individuals, companies, societies as a whole are proportionate, manageable and compatible with the principles of sustainable development

Nonetheless one policy differs, in France an ethic law exits and involves that the contractor or the consultant can't realize analyse and the remediation in a same time for a site. In Britain, the remediation can happen for three reasons:

- Voluntary: know what is causing contamination
- Planning: redevelop a site and as part of planning the remediation of a site is needed
- Part 2A: local council believes the site is contaminated

For each case, the regulators are; local authorities, contaminated land officers and EA.

4.1 Approaches of this comparison

This project has not been random project choice. The topic was chosen because it is an area of my tutor, Dr Russell THOMAS, specialises in and undertakes researches. Also Parsons Brinckerhoff has been involved in the investigation and remediation of gasworks for over 30 years. Moreover the gas industry has an important roles and changer de the daily life.
I have started to read many legislations and guidelines like:

- Les outils en appui aux démarches de gestion des sites pollués
- Contaminated land guidance (Environment Agency Part 2A)
- Remedial targets frameworks

I was able to read reports in Gaz de France to have a better understanding. The first report was a direct application of the French law (computations of risks) and the second one was an adaptation of the law by using 'Etude semi générique". This is based on detailed risk assessment, in order to "*verify the conditions of application for comparing the measured concentration in a soil to rehabilitation objectives defined for the identified products as tracers of pollution from former gasworks*". In the UK, National Grid does not have this kind of guideline and consultant pr contractor apply directly the law.
The goals are still the same.

4.2 Awareness of the site

Before analysing a site, this is essential to read all previous reports and investigations undertaken. This step allows being aware of potential accidents on-site and if treatments have been already realized. In both countries the necessary information are accessible to contractors or consultants.
This is also important to know the history of the site. In France many tools have been developed to facilitate data access, like BASIAS. In Great Britain, the archives are more used and each local authority has a list of sites they suspect could be contaminated. However nothing (data, information concerning previous pollution) is published in a public domain. We could think this is an economic issue in the UK; the government by selling former gasworks would probably secure sales. But the Soil Framework Directive suggests English should have this in Britain. The history of former gasworks in France like in the UK is generally known respectively by GDF or National Grid, when they have not been nationalized in 1946. The history of the site is elementary to know the localisation of UST, we can avoid drilling into a tank or a pipe and generate an unexpected pollution.
The last measure is to delimit the site and define the concentrated zone. In France, the concentrated zone is complicated to define as no law or guideline give a genuine specificity. So client or contractor can have their own definition. That's why it is important to be agreed before starting works.

Once the site is well known by contractors or consultants diagnose can be established.

4.3 Site diagnose

This part is the key of decontaminated land treatment. This is divided in four elements:

- Conceptual site model
- Sampling plan
- Investigations
- Results and interpretation

These measures are followed in Great Britain like in France. This allows to verify if the site is adapted to the current or future use, in French it's called; Interprétation de l'état des milieu ou plan de gestion ((MEDDE, 2011). Contractors and consultants have to apply much guidance like Circulars and specific to Gaz de France "Etude semi-generique" guidelines.

4.3.1 Conceptual site model

The used tools for this drawing are similar in both countries, this is necessary to define the source, the pathway and the receptor. To this conceptual drawing can be added a numerical model; like P20, used for the two previous studies. The awareness of geology and hydrogeology of the site is primordial and need to take account into the conceptual site model. The typical pollutants from gasworks are

- PAH: naphthalene, benzo(a)pyrene (the most carcinogenic) and fluoranthene
- Hydrocarbons
- BTEX (benzene)
- Cyanide (ferric ferrocyanide)

There is an issue if the soil is considered as source because there is no specific Directive for contaminated soils. In each directive such as Groundwater Directive or IPPC/IED Directive there is a definition of contaminated land but this definition differs and doesn't have the same meaning.
Example: Waste framework Directive: any excavated contaminated land is a waste land and must be remediated. That is why in both methodologies there is no threshold value for soils but a notion of risk.
In each methodologies the air, the groundwater, the surface water, the soils and the human health are taken account as receptors. For each element risk assessment is established.

4.3.2 Sampling plan and investigation

The used methods are the same for define the sampling plan in order to characterise the media: representativeness in a whole site. This is useless to have too much samples, this is a loss of time and money. The sampling of a site involves the production of environmental and health and safety plans. These two documents are obligatory on-site as well as PPE. Only authorised and qualified person can sample.
Once the sampling plan is appropriate, the investigation of the site follows. The collection techniques need to be adequate to the site characteristics; such as the groundwater flow. This thorough and continuing search characterizes the potential pollution inside the site.
The samples need to be handled carefully for instance pollutants from gasworks can be carcinogenic or corrosive.
In the UK, the sampling is much secured and the law is very strict.

4.3.3 Results and interpretation

The laboratory results are generally screening against Standard or Target values for soil and/or groundwater. The results are able to define if the site is conformed or not to the defined use. If the results are higher than the target values, therefore the site needs remediation. After adapted treatment, the sampling is realized once again, until to obtain the target values.
The standard value doesn't involve that there is no more pollution on-site, this engages that the pollutant concentrations are acceptable regard the environment and the human health.
The standard values are related to the use of the land and the references in France and in England are similar. These values won't the same if the rehabilitation site is a commercial zone or schools. For instance the references are Drinking Water Standards or Environmental Quality Standard and can be European or specific to each country.

The computation tools are specific to each consultant and can be modified according to the site and the type of pollution. For example, the EA Remedial Target worksheet has been bespoke by Parsons Brinckerhoff in order to meet requirements.

4.3.4 Conclusion

The French and English methodologies are closed and related on similar facts which are the site needs to be adapted to the use. The current or future use of the site has to respect the environment and the human health.
The knowledge in former gasworks is more relevant in the UK, we could think the gas industry played a more important role in the social and economic development.
In France the rehabilitation of former gasworks receiving specific facilities such as schools are classified as sensitive zone. Moreover the awareness and communication campaign are very important and current, in France. This information has been given by M Gilbert, responsible to the MEDDE. In both countries, the rehabilitation of sites, included gas industry, is an economic, ecologic, social and urban challenge. The sprawl should press governments to think about urban planning. That’s why methodologies, in both countries, need to be adapted to costs and Europeans restrictions. An environmental and ecologic point of view, the sprawl involves for instance more runoff, or saturated soil water. National Grid has been involved in many communication campaigns about the rehabilitation of former gasworks. Citizens must know even if pollution occurs on-site this does not imply a risk because the contaminant concentrations are below remedial target values.
Once again the two methodologies are based on the same principles; the site (soil and/or) has to be adjusted to the current or future use, for instance sensitive facilities (schools) or commercial zone.

Conclusion

To conclude this report, the given results are satisfactory. SEREBAR system works successfully even if the monitoring groundwater is still needed. This project will be finished in 2015.
Parsons Brinckerhoff reaches requirements, which was: undertaking an environmental risk assessment of a potential pollution from Blast Furnace Slag. Nevertheless the final report will be done at the end of this year.
The study of these sites has been very constructive and was able to compare the French and English methodologies. As seen previously they have got the same objectives.

During this internship I have learnt a lot and I was able to produce positive results for each studied site.
For SEREBAR system it was interesting to investigate on a new and original project, moreover my mission gave me responsibilities. But I have to admit the investigation the Windfarm Project were more motivating and enjoyable because I had to build almost everything from the beginning to the end. It was very interesting to follow the project evolution and being able to give an interpretation for the environmental risk assessment.
This project was also innovative because I met French and English government or companies responsible. I was lucky to work with various domains: legislation, research, and practice.
Moreover I was able to discover the diversity of gasworks.

I really want to thank all Parsons Brinckerhoff engineers, people who answered to my numerous questions in France and in the United of Kingdom. Furthermore this work experience was a very good glance at a job I like.

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Appendices

Appendix 1: The Production of Gas from Coal and the Manufacture of By-Products – From Extraction to Distribution. Produced by Dr Russell Thomas

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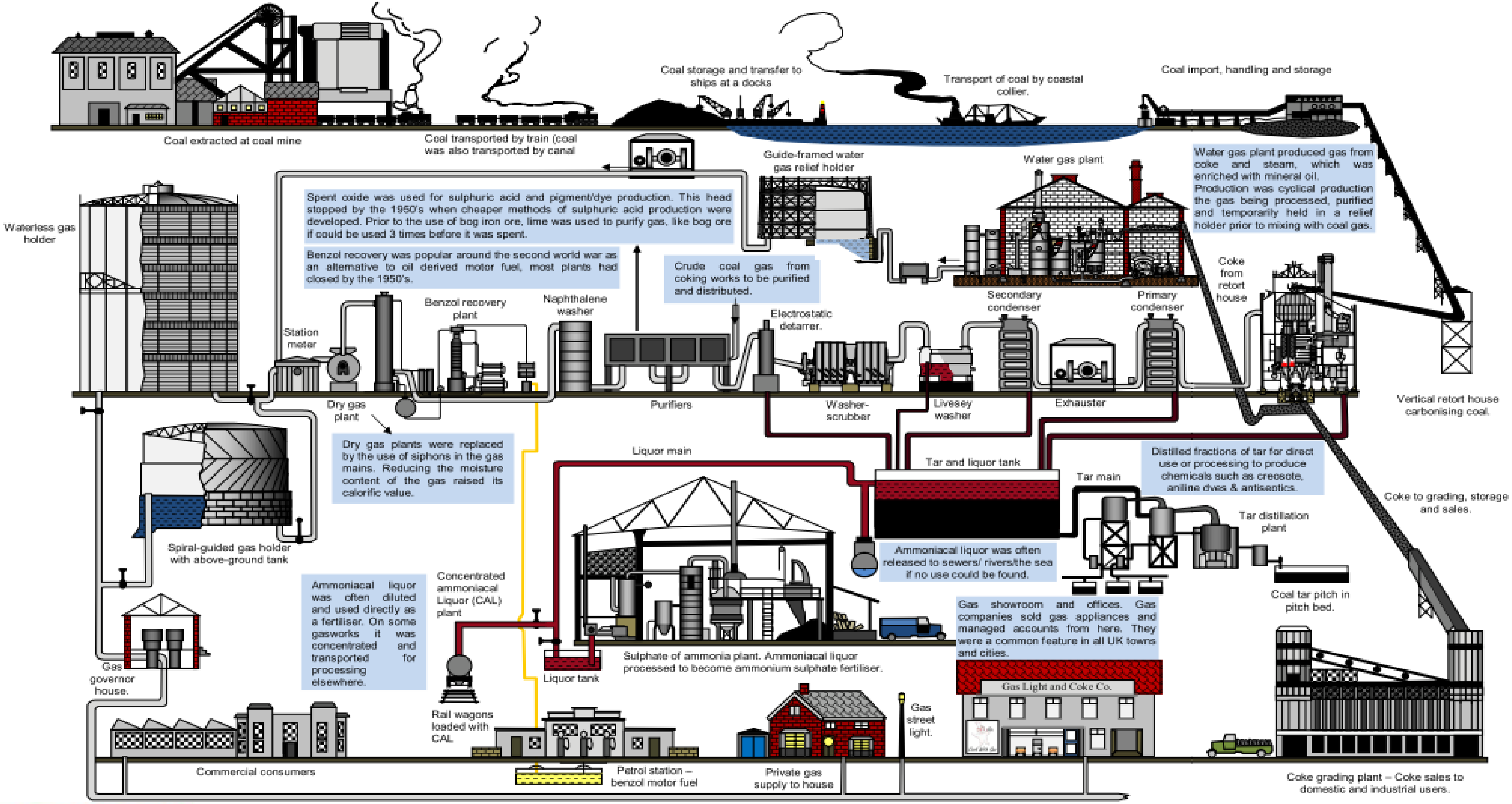
Appendix 1 **The Production of Gas from Coal and the Manufacture of By-Products – From Extraction to Distribution.**

Produced by Dr Russell Thomas (thomasru@pbworld.com)

This drawing is based on the small sketch of a similar design which was called "The making of Gas and By-Products" and featured in "Gas Utilisation of Distribution" by Norman Smith, published in 1945. The diagram shows the whole gas making process from the mining of the coal to the distribution of the gas to consumers. Efforts have been made to comment on the various uses of the by-products and to include plant not available in 1945. Some items of gas plant show a cross section of their internal workings. It should be noted that this flow diagram does not show every type of plant or every configuration of plant used on a gasworks, for examples tower scrubbers which were used prior to the washer-scrubbers. The actual configuration of plant varied significantly between gasworks and this is just a representation of a potential layout.



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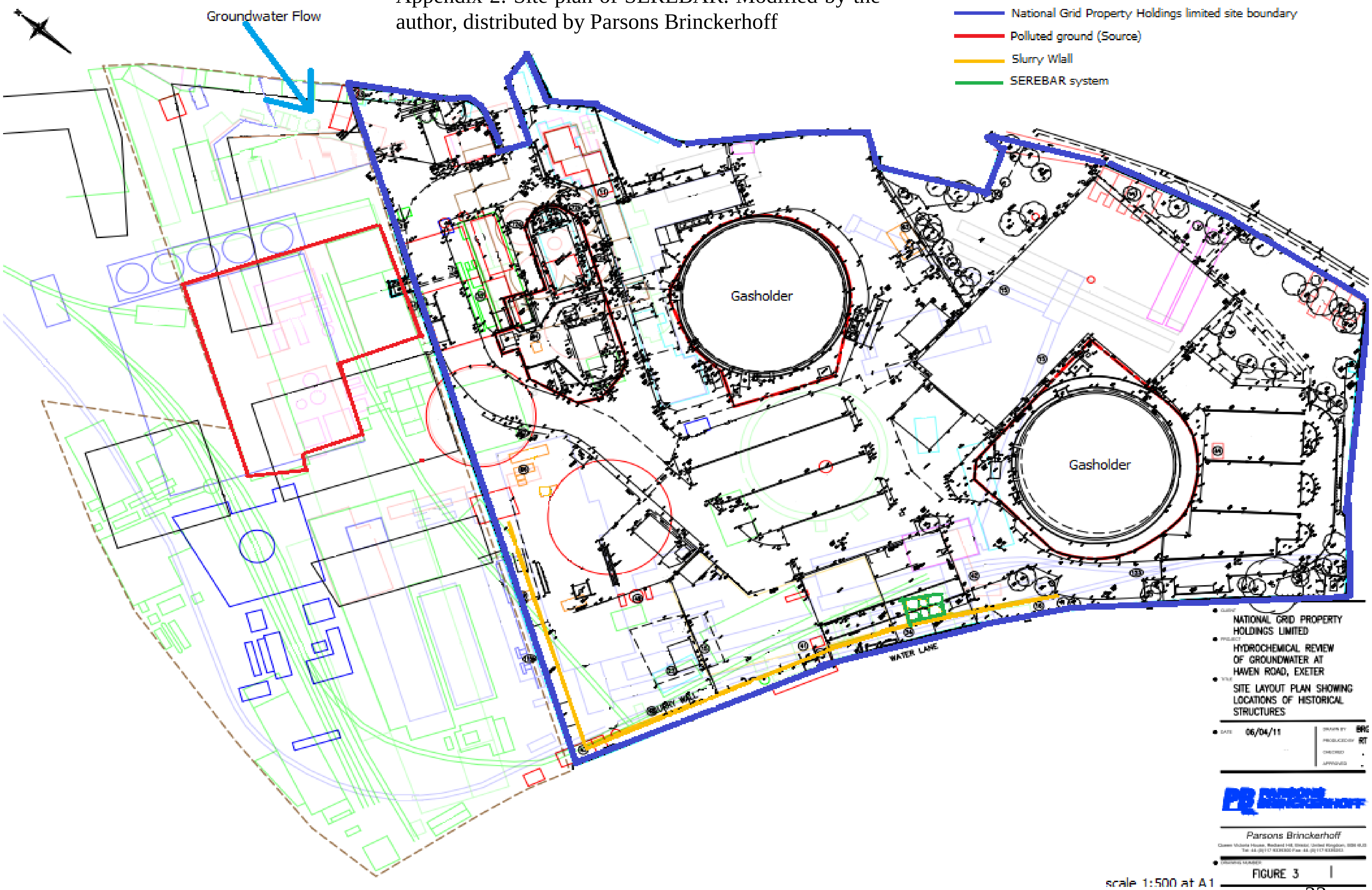
Appendix 2: Site plan of SEREBAR. Modified by the author, distributed by Parsons Brinckerhoff



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Appendix 3: Blast Furnace Slag pictures, from National Slag Association


Air cooled Coarse Blast Furnace Slag


Pelletized Blast Furnace Slag


Air cooled Blast Furnace Slag (Association, 2003)

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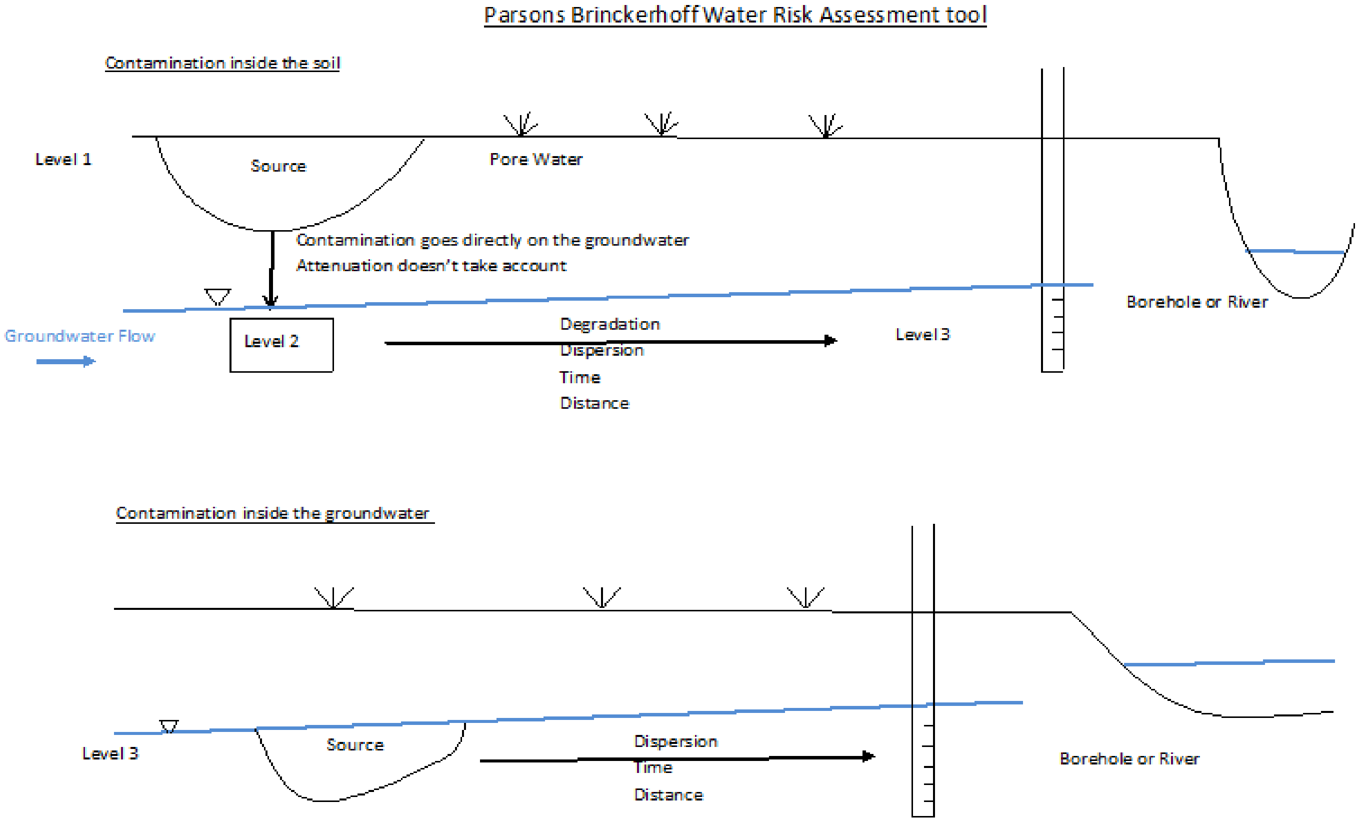
Appendix 4: Table 1: Brady and Kunkel paper

	Total Porosity, n_t		Effective Porosity, n_e	
Material	Range	Arithmetic Mean	Range	Arithmetic Mean
Sedimentary material				
Sandstone (fine)	N/A	N/A	0.02 - 0.40	0.21
Sandstone (medium)	0.14 - 0.49	0.34	0.12 - 0.41	0.27
Siltstone	0.21 - 0.41	0.35	0.01 - 0.33	0.12
Sand (fine)	0.25 - 0.53	0.43	0.01 - 0.46	0.33
Sand (medium)	-	-	0.16 - 0.46	0.32
Sand (coarse)	0.31 - 0.46	0.39	0.18 - 0.43	0.30
Gravel (fine)	0.25 - 0.38	0.34	0.13 - 0.40	0.28
Gravel (medium)	-	-	0.17 - 0.44	0.24
Gravel (coarse)	0.24 - 0.36	0.28	0.13 - 0.25	0.21
Silt	0.34 - 0.51	0.45	0.01 - 0.39	0.20
Clay	0.34 - 0.57	0.42	0.01 - 0.18	0.06
Limestone	0.07 - 0.56	0.30	~0 - 0.36	0.14
Wind-laid material				
Loess	N/A	N/A	0.14 - 0.22	0.18
Eolian sand	N/A	N/A	0.32 - 0.47	0.38
Tuff	N/A	N/A	0.02 - 0.47	0.21
Igneous rock				
Weathered granite	0.34 - 0.57	0.45	N/A	N/A
Weathered gabbro	0.42 - 0.45	0.43	N/A	N/A
Basalt	0.03 - 0.35	0.17	N/A	N/A
Metamorphic rock				
Schist	0.04 - 0.49	0.38	0.22 - 0.33	0.26

Source: McWorter and Sunada (1977) N/A = Data Not Available

Appendix 5: P20 Remedial Targets Worksheet



This drawing is an illustration of the Environment Agency's P20 Remedial Targets worksheet. The P20 worksheet uses a tiered approach to determine remedial target concentrations for each contaminant in question. The various tiers available within the software are summarised in Table 2. More detail is given in the following paragraphs. For each tier the observed contaminant concentration is compared with the derived remedial target to determine the need for remedial action.

Table 2: A summary of the Tiers available within the P20 software.

Tier/Level	Description
1	Comparison of contaminant source concentrations with applicable water quality standard
2	As 1 + unsaturated zone travel time, transport processes, biodegradation and effects of dilution in the aquifer
3	As 2 + saturated zone transport, attenuation and retardation processes. Level 3.
4	As 3 + dilution in the receptor.

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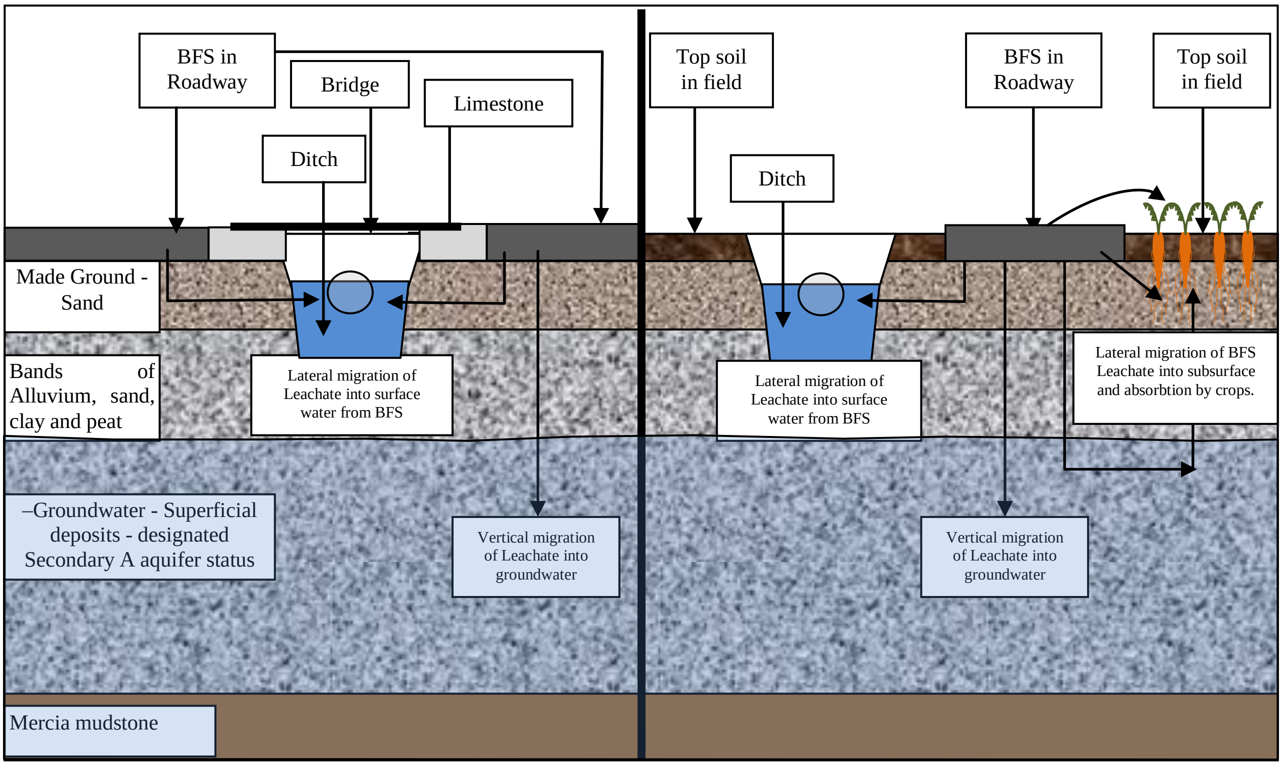
Level 1 is the simplest stage. It predicts contaminant concentrations in pore water within the site, either measured directly from leachate samples, or predicted using soil concentration analyses. Level 1 is the most conservative level as it considers neither dilution nor attenuation of the contaminant. This level is not applicable to the groundwater as the contaminants have already moved through the unsaturated zone.

Level 2, in addition to the Level 1 analysis, considers the time required for the contaminant to migrate to the groundwater, assesses the contaminant concentration at the base of the unsaturated zone, and, where data are available, enables a preliminary assessment to be carried out on the concentration of contaminants at the point of maximum dilution in the aquifer. Retardation, degradation and dilution, can be considered, in addition to the effects of fractured and porous geologies.

Level 3 assessment includes all the parameters considered in levels 1 and 2, and also models the time taken for the contaminant to migrate to a chosen off-site receptor. Attenuation, degradation, retardation and dispersion can be considered, in order to predict the contaminant concentration at the receptor.

Level 4 assessment considers dilution in the receptor. This is a special case and the assessment must demonstrate that any impact on the groundwater does not jeopardise future use of the resource or that the cost of remediation is disproportionate in relation to the improvement of groundwater or surface water quality. In moving from Level 1 to Level 4, the data and resources required increases, but the degree of conservatism decreases and therefore the cost-effectiveness of the remedial solutions are likely to improve

Appendix 5: Conceptual Site Model



Appendix 6: Table 3: General inputs

	Site Parameters	Units	Inputs	Sensitivity Range		Source of data
				Min	Max	
Unsaturated Zone	Water filled soil porosity	fraction	0.10	-	-	Conservative
	Air filled soil porosity	fraction	0.20	-	-	Conservative
	Bulk density of soil zone material	g/cm3	1.46	0.10	1.81	Median of literature values for clayey peat sand (Wiedemeier 1995)
	Fraction of organic carbon (in soil)	fraction	0.0135	-	-	Conservative
	Infiltration	m/d	8.30E-04	-	-	Recorded at the River Trone at Auckley, 20.84km from the site. Annual rainfall of 608mm
	Length of contaminant source in direction of groundwater flow	m	4.8	-	-	Estimated from W to E across source area
Saturated Zone	Saturated aquifer thickness	m	10.70	6.00	12.70	Estimated from BGS boreholes
	Hydraulic Conductivity of aquifer in which dilution occurs	m/d	0.09	0.0009	0.12	Estimated from literatures, (J.P Powers *et al*., 2007)
	Hydraulic gradient of water table	fraction	0.00148	0.00096	0.00151	Estimated site gradient
	Width of contaminant source perpendicular to groundwater flow	m	51.57	-	-	Estimated from N to S across source area
	Plume thickness at source	m	9.92	-	-	Calculating from mixing zone thickness
	Fraction of organic carbon (in aquifer)	fraction	0.0029	-	-	Conservative
	Bulk density of aquifer materials	g/cm^3	1.46	-	-	Median of literature (Wiedemeier 1995)
	Effective porosity of aquifer	fraction	0.32	0.31	0.33	Conservative effective porosity (Brady & Kunkel), 2003
	Distance to compliance point	m	6	-	-	Closest receptor

Determinant	GAC (mg/l)	Maximum Recorded BFS Concentration (mg/kg)	Maximum Recorded Field Soil Concentration (mg/kg)	Maximum Recorded Surface water concentration (mg/l)	Kd l/kg	Henry's Constant	Half Life (days) Utilised Value
Aluminium	0.2(2)	37427	22330	0.084	1500	N/A	9E+99
Ammonium	0.04(2)	5	5	0.1	9000	N/A	9E+99
Arsenic	0.01(1)	5	21.3	0.005	29	N/A	9E+99
Barium	0.1(2)	502	379	0.293	41 (5)	N/A	9E+99
Cadmium	0.00009(3)	0.5	0.6	0.001	75(5)	N/A	9E+99
Chloride	250(2)	0.1	0.1	343	100	N/A	9E+99
Chromium	0.0032(3)	64	46	0.005	19	N/A	9E+99
Copper	0.04(3)	6	26	0.005	35	N/A	9E+99
Iron	0.2(1)	11354	38990	0.484	25 (5)	N/A	9E+99
Lead	0.0072(3)	18384	138	0.001	900 (5)	N/A	9E+99
Manganese	0.05(2)	18384	943	0.91	65	N/A	9E+99
Mercury	0.0003(2)	0.5	<0.5	0.0001	52	0.47	9E+99
Molybdenum	0.07(2)	4304	5	0.518	20	N/A	9E+99
Nickel	0.15(2)	5	40	0.005	65 (5)	N/A	9E+99
Selenium	0.01(2)	3.4	1.1	0.005	5	N/A	9E+99
Sulphate	250(2)	0.2	0.1	931	100	N/A	9E+99
Vanadium	0.02(2)	198	63	0.005	100	N/A	9E+99
Zinc	0.05(3)	40	154	0.02	62	N/A	9E+99

(1) River Basin District Typology, Standard and Groundwater Threshold Value (water Framework Directive) (England and Wales) 2010
(2) Water Supply Regulations (2000)
(3) River Basin District Surface Water and Groundwater Classification (Water Framework Directive) (England and Wales) 2009

Appendix 7: Table 4 : Final Results

			Level 1 Soil						Level 2 Soil						Level 3 Soil						Level 3 GW		
	Max Concentration		Target1	Exc.d	Target2	Exc.d	Target3	Exc.d	Target1	Exc.d	Target2	Exc.d	Target2	Exc.d	Target1	Exc.d	Target2	Exc.d	Target2	Exc.d	Target1	Exc.d	Cf
	Soil	GW	Leachate		Soil (UnCal)		Soil (Cal)		Pore Water		Soil (UnCal)		Soil (Cal)		Pore Water		Soil (UnCal)		Soil (Cal)		GW		
Determinant	mg/kg	mg/l	mg/l		mg/kg		mg/kg		mg/l		mg/kg		mg/kg		mg/l		mg/kg		mg/kg		mg/l		
Aluminium	22330,00	0,084	2,00E-01		3,00E+02	*	3,00E+02	*	2,36E-01		3,54E+02	*	3,54E+02	*	5,10E-01		7,65E+02	*	########		3,10E-01		1
Ammonium	5,00	0,1	4,00E-02	*	3,60E+02		3,60E+02		4,72E-02	*	4,25E+02		4,25E+02		1,02E-01		9,17E+02		7,44E+62		6,20E-02	*	1
Arsenic	21,30	0,005	1,00E-02		2,91E-01	*	2,91E-01	*	1,18E-02		3,43E-01	*	3,43E-01	*	2,46E+142		7,15E+143		2,36E+39		#NUM!	#NUM!	1
Barium	379,00	0,293	1,00E-01	*	4,11E+00	*	4,11E+00	*	1,18E-01	*	4,85E+00	*	4,85E+00	*	2,55E-01	*	1,05E+01	*	8,04E+70		1,55E-01	*	1
Cadmium	0,60	0,001	8,00E-05	*	6,01E-03	*	6,01E-03	*	9,45E-05	*	7,09E-03	*	7,09E-03	*	2,96E+40		2,22E+42				1,26E+112		1
Chloride	0,10	343	2,50E+02	*	2,50E+04		2,50E+04		2,95E+02	*	2,96E+04		2,96E+04		6,37E+02		6,38E+04				3,88E+02		1
Chromium	46,00	0,005	3,20E-02		6,10E-01	*	6,10E-01	*	3,78E-02		7,21E-01	*	7,21E-01	*	8,16E-02		1,56E+00	*			4,96E-02		1
Copper	26,00	0,005	4,00E-02		1,40E+00	*	1,40E+00	*	4,72E-02		1,66E+00	*	1,66E+00	*	1,02E-01		3,57E+00	*			6,20E-02		1
Iron	38990,00	0,484	2,00E-01	*	5,01E+00	*	5,01E+00	*	2,36E-01	*	5,92E+00	*	5,92E+00	*	5,10E-01		1,28E+01	*			3,10E-01	*	1
Lead	138,00	0,001	7,20E-03		6,48E+00	*	6,48E+00	*	8,50E-03		7,66E+00	*	7,66E+00	*	1,83E-02		1,65E+01	*			1,12E-02		1
Manganese	943,00	0,91	5,00E-02	*	3,25E+00	*	3,25E+00	*	5,91E-02	*	3,84E+00	*	3,84E+00	*	2,64E+49		1,72E+51				4,17E+130		1
Mercury	0,50	0,0001	3,00E-04		1,56E-02	*	1,56E-02	*	3,54E-04		1,85E-02	*	1,85E-02	*	7,65E-04		3,99E-02	*			4,65E-04		1
Molybdenum	5,00	0,518	7,00E-02	*	1,40E+00	*	1,40E+00	*	8,27E-02	*	1,66E+00	*	1,66E+00	*	1,78E-01	*	3,58E+00	*			1,09E-01	*	1
Nickel	40,00	0,005	1,50E-01		9,76E+00	*	9,76E+00	*	1,77E-01		1,15E+01	*	1,15E+01	*	3,82E-01		2,49E+01	*			2,33E-01		1
Selenium	1,10	0,005	1,00E-02		5,07E-02	*	5,07E-02	*	1,18E-02		5,99E-02	*	5,99E-02	*	2,55E-02		1,29E-01	*			1,55E-02		1
Sulphate	0,20	931	2,50E+02	*	2,50E+04		2,50E+04		2,95E+02	*	2,96E+04		2,96E+04		6,37E+02	*	6,38E+04				3,88E+02	*	1
Vanadium	63,00	0,005	2,00E-02		2,00E+00	*	2,00E+00	*	2,36E-02		2,36E+00	*	2,36E+00	*	2,19E+87		2,19E+89				1,22E+228		1
Zinc	154,00	0,02	5,00E-02		3,10E+00	*	3,10E+00	*	5,91E-02		3,67E+00	*	3,67E+00	*	1,03E+55		6,42E+56				8,13E+144		1

Red star means: exceedance
#NUM! means: value that the value is very low

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Résumé

Ce rapport compare deux méthodologies, anglaise et française. Les méthodes et principes utilisés sont illustrés par deux sites étudiés en Grande-Bretagne. Pour des raisons de confidentialité les noms et la localisation précise des sites ne seront pas donnés.
Les sites étudiés ont un point commun, ils sont tout deux des anciennes usines à gaz. Lorsque la production de gaz a cessé sur ces deux sites, les usines ont été vendues à l'Etat ou à des particuliers, les bâtiments ont été démolis et le site a été réhabilité. Cependant des sous-produits et/ou des déchets n'ont parfois pas été éliminés en totalité dans les normes standards. Les autorités locales ou un agent des sites pollués sont généralement tenus au courant et le site est classé dans le but d'évaluer s'il pose un risque pour l'environnement (écologie, faune, flore), les masses d'eau et la santé humaine. Si le risque existe, un moyen doit être trouvé pour y remédier soit en enlevant le sol contaminé soit en traitant sur place l'eau et/ou le sol.

Ces sites sont tous les deux traités *in-situ*. Pour le premier un système de traitement innovateur a été créé. Ce traitement biologique fonctionne avec succès depuis 2004. Ma mission a été de surveiller et d'échantillonner l'eau souterraine polluée.
Un sous-produit de la fabrication de fer (Blast Furnace Slag) a été utilisé sur le second site pour la construction de routes, mais son utilisation a entraîné une pollution. Pour ce site j'ai dû effectuer une évaluation du risque pour les eaux souterraines et de surface, ce qui a impliqué des recherches scientifiques, de faire un résumé des rapports précédents, d'échantillonner le terrain (eaux et sol) et de donner les recommandations nécessaires et adaptées.

Les deux méthodologies sont proches mais utilisent des outils et des références différentes. La réalisation de cette étude m'a permise de collaborer avec Gaz de France, de rencontrer deux responsables, une au BRGM (Bureau de Recherches Géologiques et Minières) et un autre au MEDDE (Ministère de l'Ecologie, du Développement du durable et de l'Energie). Ces rencontres ont été très constructives et m'ont aiguillée sur les directives utilisées en France.

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