An Innovative and Novel Technique Used for the Remediation of Highly Contaminated Galligu Soil Within the Borough of Halton

Introduction

The Borough of Halton sits at the northwesterly corner of Cheshire on both sides of the Mersey estuary and encompasses the two towns of Runcorn, on the south bank of the Mersey and Widnes of the north bank. The Borough of Halton also includes the villages of Hale, Moore, Daresbury and Preston Brook. It is situated between Liverpool and Manchester and is the lowest bridging point across the River Mersey.

A recently published document by Halton Borough Council entitled "Building a Better Future" describes the Council’s corporate plan and is a key tool which links the Halton vision to the Council’s plans and strategies for the future. This document helps to translate ideas into action on the ground. A key aspect of this document aims at promoting sustainable development within the borough to ensure that Halton becomes a place where people are happy and proud to live, work and raise their families, in which good homes, amenities and a pleasant environment are achieved.

Halton’s Environmental Legacy

The Borough of Halton lies centrally within an area known as the Mersey Belt. This area was at the forefront of the Victorian industrial revolution and consequently developed a significant manufacturing base, including pharmaceutical, petrochemical and heavy chemical industries. To this day the area still continues to be a major area for manufacturing industries. However, in recent times the region’s economy has increasingly moved away from its reliance on traditional manufacturing industries, with a growing number of significant smaller diverse industries.

Industrial activity in the Borough of Halton over the years has been a major contributor to the many and varied types of contamination. Although the stricter and more effective environmental regulations introduced over the last decade has led to a significant drop in pollution of the surrounding environment, Halton is recognised as one of the most highly contaminated parts of Britain.

The Council is actively engaged with the community, stakeholders and regulators through a number of key strategies, including; regeneration, economic development, sustainable development/agenda 21 and the Unitary Development Plan, in order to address the many challenging environmental issues.

Halton was the birth place of the Victorian chemical industry, and still is, the home of the UK’s Alkali and chemical industry. In particular Halton was home to the Le Blanc chemical process.
The Le Blanc process converted common salt into soda ash using sulphuric acid, limestone and coal. The waste by-products from this process were harmful hydrochloric acids, nitrogen oxides, magnesium and sulphur. As a result of these noxious chemicals, the ring of dead and dying grass and trees that surrounded these sites could easily identify many manufacturing sites.

The problem became so acute that, in 1839, a petition against the Le Blanc Process complained that,

"The gas from these manufactories is of such a deleterious nature as to blight everything within its influence, and is alike baneful to health and property. The herbage of the fields in their vicinity is scorched, the gardens neither yield fruit nor vegetables; many flourishing trees have lately become rotten naked sticks. Cattle and poultry droop and pine away. It tarnishes the furniture in our houses, and when we are exposed to it, which is of frequent occurrence, we are afflicted with coughs and pains in the head...all of which we attribute to the Alkali works."

Needless to say, many people strove to replace the Le Blanc Process with something less offensive to nature and mankind alike.

In 1873 a new process for producing soda ash was developed. This was known as the Solvay Process and produced no hazardous waste streams that risked human health. By 1880 the Solvay process was rapidly replacing the Le Blanc Process and consequently many sites within the Borough of Halton became derelict, but not before significant quantities of waste had been dumped in the surrounding area, particularly in and around the low-lying areas of "sailing" marshes adjoining the River Mersey. The alkaline waste from this industry became locally known as "Galligu".

The problems of Galligu contaminated sites have been compounded over the last hundred years by indiscriminate tipping of other industrial waste products on the same sites from the chemical industry, tanneries, copper smelting, soap manufacturing, phosphate fertiliser manufacture and asbestos cement wastes. Typically the depth of contamination extends to a depth of 3-4 metres and occupies an area of up to 400 hectares.

Since 1974, Halton Borough Council has been instrumental in bringing back into use some 180 hectares of Galligu contaminated sites, 129 hectares for green end use and 51 hectares for hard end use. This represents a public investment of more than £20m from the Derelict Land Grant and the Land Reclamation Programme. Unfortunately, "cherry-picking" the easiest, and avoiding the most expensive and dangerous sites achieved these results. Typically, remove and replace methods were the preferred method of remediation, thus moving the problem elsewhere. This method is now unacceptable and other, more environmentally acceptable solutions have to be investigated for future sustainable development within the Borough in accordance with the "Building a Better Future" document/strategy.
Redevelopment and Remediation of Hutchinson Street – Widnes

The Problem

A recently developed site in Widnes was one of these contaminated areas. The site is roughly square in shape, and is approximately 2.5 Ha in area. The site is bounded by roads (Desoto Road East, Hutchinson Street and Wandsworth Way) on three sides and a sectional concrete fence bordering a freight container storage yard to the south. The estuary of the River Mersey lies about 650 m to the south. All watercourses nearer to the site run in culverts. The purpose of the development was to create recreation grounds, in the form of a rugby pitch, an all weather practice pitch and amenities for a local amateur rugby club.

The site, referred to as Hutchinson Street, was originally farmland due to its proximity to the Mersey. However, the site was purchased by industry in 1875 and used for the infilling of locally-generated industrial fills including alkali wastes, boiler ash and metal-smelting wastes. By 1891, the site was occupied by two alkali manufacturing works, a manure works and a sawmill. These are no longer present and signs of building debris from these plants were evident across the site.

The ground on the site is made up of a variable mix of ash, demolition rubble, timbers, brick foundations, culverts, alkali waste and various contaminated deposits. The depth of this fill typically varied between 2.3 m and 3.3 m, mostly black, organic alluvium clay underlies the fill, which has a firm to soft consistency. Evidence of heavy metal contamination within the alluvium clay inferred cross contamination over the years had been taking place.

Typical Leblanc alkali waste deposits, or “galligu” was found in the majority of locations on the site. Excavation of the saturated Leblanc waste below the local water table resulted in the production of a loose slurry, which was fairly free draining. The original Ground Investigation reported moisture contents for the Leblanc waste ranging from 31% to 138%, with a range of 40 to 60% being the typical value. Indiscriminate waste tipping over the years has added to the problem and as a result the land has been classified as high or very highly contaminated. Contamination includes; arsenic, lead, zinc, cadmium, copper, sulphurous waste deposits (galligu), nickel and chromium. The pH of the contaminated fill material varied from 2.6 to 12.2 pH. Typically the low pH values were recorded in the upper 1.0 to 2.0m of fill.

One of the main environmental concerns about the contaminated fill was the level of metal contamination, particularly arsenic, cadmium, copper and zinc. At low pH values (typically less than 7 pH) the solubility and hence mobility of these substances is high. This combination of factors can result in the heavy metal being easily and readily dissolved and mobilised resulting in a high leachability potential that would pose a risk of pollution to the River Mersey.

Due to the highly contaminated nature of the site, remediation was required before development of the site could take place. Ground modelling and
extensive site investigations were undertaken to estimate the extent of the contamination. Data taken from 4 previous site investigation reports and site contours demonstrated that the volume of contaminated fill on the site to be in the region of 87,000m³. To prevent heavy metal pollution of the Mersey via cross-contamination, removal of the contamination to landfill was considered, however, this was rejected due to the volume of the material required to be taken from site and the volume of clean inert material that would have to be returned to site. This would have represented over 11,000 lorry movements as compared to the 100 lorry movements for the new process. This was not an acceptable sustainable or economically viable solution. Other more cost-effective and sustainable solutions were therefore investigated.

The Solution

Removal and replacement of the contaminated fill at Hutchinson Street was not a viable development option, therefore alternative solutions needed to be investigated. One such alternative investigated was the in-situ and/or ex-situ remediation of the contaminated material, thus keeping the contaminated soil on site. This therefore eliminated the need for removal. However, due to the type and quantities of contaminants present very few treatment processes appeared to be suitable, primarily due to the alkali nature of the “galligu” deposits.

In 1999 Halton Borough Council invited interested consultants and contractors to attend a full day seminar to discuss the various ‘Alternative Technologies’ and how they could be applied to the ‘Galligu’ problem. Following a very successful day, several consultancies and contractors offered a variety of possible solutions. The Council, working very closely with the Environment Agency, decided the way forward was to carry out a series of site trials to fully evaluate these ‘Alternative Technologies’. The trials, involving full sized plant and machinery, utilised traditional lime stabilisation techniques, but with the addition of specialist additives to the cement/lime mix to cope with the contamination. These trials took place in May 2002 and were fully supervised and evaluated by independent environmental consultants and the Environment Agency. The results from the trials were very encouraging and following extensive monitoring over 9 months and the evaluation of costs, it was decided that a specialist cement additive known as ‘Powercem 2’ supplied by PowerBetters of Leeds provided the results required at the most competitive price.

The insitu stabilisation and solidification of contaminated soil technique has been widely and successfully used in North America for the last 25 years for the treatment of numerous organic and inorganic waste streams. The technique basically comprises the mixing of hydraulic binders, namely Ordinary Portland Cement (OPC), Calcium Oxide (quicklime) and Pulverised Fuel Ash (PFA), either in combination, or individually into the contaminated ground. The pursuing chemical reaction creates a high alkaline environment that results in the production of cementitious compounds, similar to that produced in concrete, that solubilises, immobilises and encapsulates the
contaminants within the cementitious hydrous gel. This "lock-in" effect dramatically reduces the leachability potential of the contaminated soil, thus reducing, and in some cases, eliminating the risk of cross contamination to water courses or "clean" neighbouring soil.

Although successfully used in North America the technique had not been used extensively in the UK. In fact the only known case where such a technique had been used was during the groundworks for the Millennium Dome, where it had been utilised to a very limited extent. This type of remediation solution appeared to be a viable option.

The trial mixes investigated included a traditional lime and cement mix together with novel and innovative secondary additives/mixes that had never been utilised full scale before in the UK for stabilisation and solidification remediation. Powercem was also investigated to evaluate its potential. During the summer of 2002 five trial bays, approximately 100m² in area were constructed by Powerbetter. The products/mixes utilised in these bays are given below.

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<td>Bay 1</td>
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Each trial bay was subjected to a comprehensive regime of in-situ and ex-situ testing in order to investigate the optimum mix in which engineering, environmental and economical criteria were achieved. The tests undertaken included the measurement of strength, chemical composition, permeability and leachability.

In-situ CBR tests undertaken 7 days after treatment works revealed strengths in excess of 50% for all trial bays compared to an untreated strength of between 1 and 3%. Laboratory curing of retrieved treated samples demonstrated further increases in strength up to a value of 260% after a 28 day cure period. The OPC/Lime and OPC/Powercem blend demonstrated the highest strength gains, however, the OPC/Powercem blends produced a much more flexible a less brittle material. This was an important criteria as cracking of the stabilised layer could lead to water infiltration resulting in cross contamination and the leaching of the contaminants.

Permeability testing after 28 days demonstrated significant improvement. The permeability of the untreated soil varied from $10^{-8}$ to $10^{-6}$. All material tested from the test bays demonstrated permeability values in the order of $10^{-8}$. A value of $0.22 \times 10^{-8}$ was recorded for the OPC/Powercem material. The lowest permeability recorded.

Leachate testing demonstrated significant reductions when compared to the untreated galligu soil. The reductions in leachability were greatest for the
OPC/Powercem blends, where leachate concentrations for cadmium (2µg/l), chromium (12µg/l), nickel (1µg/l), zinc (2µg/l) were all below threshold values stipulated in the Water Supply (Water Quality) Regulations 2000. Values for lead (30µg/l) and arsenic (20µg/l) were slightly higher than the threshold values, but significant reductions were recorded compared to the untreated material. Typical concentrations in the untreated material included; lead (1,296 µg/l), zinc (1,570 µg/l) and arsenic (580 µg/l).

In principle all bays performed well and met the given criteria, i.e. significantly improved strength properties and reduced permeability. However, of all the mixes tested the OPC/Powercem 2 mix yielded the better performance in terms of engineering and environmental criteria, but, perhaps more significantly the cost of treatment was significantly less per cubic metre when compared to the other mixes.

As a result of these highly successful field trials full-scale remediation operations commenced in September 2003. These are due to be complete by the end of October 2003, with the landscaping programmed for the coming months. The remediation works comprise the construction of a 350mm insitu stabilised contaminated soil with a 200mm layer of reclaimed "clean" railway ballast placed on top. A Teram geotextile was then placed on top with a 100mm covering of sand with topsoil and turf.

Conclusions

Over a hundred years of industrial development in the Borough of Halton has left a legacy of contamination for future generations to contend with. Development of this land for housing, industrial or recreational use requires careful consideration as typical remove and replace remediation options are now no longer a sustainable option. Further more with the onset of new and restrictive European legislation it will no longer be acceptable for developers of contaminated land to remove and replace the contamination as this is moving the problem from one area to another. It is critical that new and innovative techniques of remediation are investigated to ensure sustainable development is achieved.

The redevelopment of the Hutchinson Street site is a pioneering and innovative leap forward for Halton Borough Council. Faced with a possible remove and replace remediation cost of £1.6 million The Major Projects Department of Halton Borough Council decided to investigate other remediation solutions. Careful consideration and field-testing of these has led to an appropriate solution being implemented. Although widely used in the USA stabilisation and solidification of contaminated soil has not been adopted in the UK and to date has now only been used twice, once, to a very limited extent at the Millennium Dome and now in Widnes on a 2.5 Ha site. Stabilisation and solidification utilising Powercem, a secondary additive has never been used in the UK. The work is so new and innovative that other local authorities; consultants and contractors have showed considerable interest. Two articles, one in Sustain magazine and the other in Ground Engineering describing the work are pending. The work is also likely to attain a CL:AIRE
demonstration project status. This will ensure further monitoring and a wider uptake of the technique for remediation of contaminated land that was pioneered in the Borough of Halton.

Finally, the cost saving to the local authority in adopting the remediation process is in the region of £800,000. A significant saving to the taxpayers of Halton and when the process is utilised throughout the UK it will also save valuable tip space complying with the new Landfill Directive and it will also save quarried aggregate. The saving to the environment also includes the dramatic reduction in HGV traffic.

This innovative process offers a sustainable, economic and environmentally acceptable solution and way forward to deliver the Governments Brownfield Development objectives.

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