DECONTAMINATION AND REMEDIATION WORKS AT ALBRIGHT & WILSON, PORTISHEAD

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ABSTRACT

In order to permit redevelopment of a valuable waterside site, Albright & Wilson undertook the remediation of their former phosphorus refinery at Portishead Docks. The task was complicated by the fact that the phosphorus plant had been built over former timber yards and, more significantly, an oil refinery.

Arup were appointed as Environmental Consultant for the works and this paper briefly describes the history of the docks, the complex legal agreements under which the work was done with an outline of the activities on site.

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The former Albright & Wilson (A&W) site at Portishead was identified as contaminated as a result of both its history of use and records of A&W activity on the site. The history of Portishead Docks and the site is outlined below:

- New docks at Portishead were proposed by the landowners, Bristol City Council, in 1870 and work started in 1873 and after several delays was completed by 1879 at a cost of £160,000. At this time all the wharfage was on the north west side of the dock.

- In 1903 the Council authorised development of the southeast side of the Port with the construction of a 600-foot long timber wharf and a 200-foot jetty with 10 acres of stacking ground behind.

- The Anglo-Saxon Petroleum Company Limited leased three acres of land in 1908 to store and tranship 'motor spirit'. The first tanker docked in 1909.

- At the beginning of the Great War there was a shortage of toluene as coal distillation could not keep up with the demand of the explosives manufacturers. In order to make up the shortfall, a refinery was transferred from Rotterdam in the face of the German advance and re-erected at Portishead in 1915 and supplied with crude oil from Borneo from which toluene could be extracted by Shell-Mex.

- The Asiatic & Anglo-Saxon Petroleum Company expanded their tankage at Portishead and also set up a can-making works to enable it to fulfil a government contract to supply petrol to the Front in four-gallon cans. In the early part of the war 70% of all petrol used by the BEF was sent from Portishead.

- During the war 18,500 tons of toluene were produced as well as a 'large quantity' of xylene that was re-exported to France for their explosives industry.

- It is not clear if refining continued after the war but petrol storage in 12 circular tanks and transhipment continued with 'exports' mainly in tins and tankers by rail.

The Docks 1930

- By 1935 W H Keys Limited had taken over the installation. The trade directory of that year lists them as ‘bitumen refiners’ and it is understood that they specialised in the manufacture of bitumastic products including flooring blocks. In 1947 there were only two tanks remaining.

- In 1952 Albright & Wilson took a lease and commenced construction of a phosphorus refinery. The remaining oil tanks and associated buildings were removed during site clearance works. Coarse clinkery ash from Portishead ‘A’ power station were used as well as imported crushed rock and “quarry waste” to raise site levels.

The Docks 1960

- Phosphorus manufacture on the site ceased in 1970 and from 1972 the furnaces, calciners etc were demolished. Circular tanks were erected to the northeast of the old furnace building in the 1960s and after the furnaces were switched off they received liquid phosphorus from a new works in Newfoundland. It was stored at 60°C prior to transhipment elsewhere in drums or in liquid form in road tankers.

- During the life of the works ‘mud,’ consisting mainly of feedstock fines contaminated with phosphorus from precipitators, condensers and process storage tanks as well as other debris were disposed of in ‘lagoons' dug into the northern part of the site. Silicate slag was also stored in this area. The slag was a valuable by-product due to its hardness and friction properties and was sold for use as road metal. During the 1970s demolition, phosphorus contaminated rubble and pipework was also buried in the lagoons as well as in various sumps and the slag bays in the old works.

- In the early 1990s, in anticipation of the works becoming redundant, Albright & Wilson started to investigate the various lagoons and commenced decontamination works.

A&W had an obligation under their lease from Bristol City Council (BCC) to return the site to its original condition prior to vacating the site. A&W had ceased refining operations so that the site adjacent to the former dock was surplus to requirements and available for redevelopment. However a considerable period remained on the lease so the developers, Portishead Quays Consortium (PQC) with BCC agreed to fund A&W to bring forward the timing of the decontamination works and the surrender of their lease. Hence the process and agreements for decontamination link the tenant and polluter (A&W), the land owner (BCC) the planning authority (NSC) and the developer (PQC) in legal, planning, financial and the physical decontamination works.

Arup were appointed by the Consortium in 1995 to carry out site investigations and a document review to establish the scale and nature of the health and environmental risks posed by site in its then condition, and to devise a schedule of decontamination works appropriate to its future use as a mixed residential/commercial development.

A&W made available record documents relating to both their occupation of the site and the remediation works A&W had undertaken in the period following the cessation of phosphorus manufacture in 1970. Information was also obtained from discussions with NSC, HSE, HM Inspector of Pollution and the Environment Agency (previously the NRA) to develop an indication of likely spread of materials that could pose a risk to health or the environment.

A series of trial pits were dug across the site, the exposed ground examined and samples recovered and analysed.

In the Risk Assessment Report the following hazards are identified:

- **Phosphorus**, in particular the yellow allotrope which will spontaneously combust or fume on contact with air.

- **Heavy Metals**, in particular cadmium and arsenic were identified in samples taken from shallow fills. Solubility tests indicated that leaching from solid form was unlikely and therefore the risk to water bodies and groundwater was small.

- **Hydrocarbons** were identified in the area of the refinery installation that predated A&W occupation of the site. Adjacent water bodies, including a lagoon within the refinery area, showed no signs of oil film indicating that the hydrocarbons were neither mobile nor volatile. However these products can affect plastic pipes and buried structures and have a potential to release odours.

- **Slags and Phosphate Fines** are by-products of phosphorus refining, and emit gamma radiation at a similar rate to naturally occurring 'radon' areas of the country.

- **Other Contaminants** were identified from A&W records including domestic/office refuse, drums of arsenic or cyanide and minor oil deposits from machinery or fuel tanks, PCBs from electric apparatus, asbestos and other deleterious building materials.

The Risk Assessment set out treatment options for each hazard, consistent with the proposed end uses. The plans at that time noted commercial development of retail and office/ warehouse uses, housing in apartments but no private gardens, public open space, roads, footpaths and car parking areas. The assessment also recognised that the buildings to be demolished included clean brick and concrete materials which when crushed would provide clean granular fill.

The obligations on various parties are defined in a series of back-to-back planning/legal agreements. These include lease surrender, agreement to sell/buy the site, Planning Section 106, decontamination funding, flood defence construction and adoption, warranties and cross-indemnities.

Albright & Wilson had started 'decontamination' works in a small way in the early 1990s prior to Arup's involvement by, amongst other things, carrying out an archive search for details of any disposal pits as well as contacting former workers. From this work they prepared a plan marked up with a number of suspected pits together with a schedule of other potential hazards. These included reports of there being drums of cyanide and other toxic waste buried on the site as well as a dragline crane which had apparently fallen irretrievably into one large pit.

The principals of the decontamination works as set out in the SDW were fairly straightforward. For most zones this involved excavating the 'made ground' to the natural clay alluvium, separating slags, phosphate fines and 'oversize' for disposal or crushing and phosphorous materials for treatment. The phosphorus-contaminated materials included 'mud', partially full drums and rubble from the old furnace and refinery plant. The latter included concrete and brickwork into which phosphorus vapour had infiltrated and solidified as the red allotrope. This was easily identifiable by its distinctive reddish hue and the tendency to 'spark' or ignite when struck. The phosphorus 'mud' was fine particulate matter, such as anthracite, silicates and limestone that had come out of the furnaces along with the phosphorus vapour and had collected in the condensers and the storage tanks. The cleaned materials were then replaced and compacted in general agreement with the requirements of the DoT earthworks specification.

In the 1980's, Albright & Wilson had built three 'stills' in which skips of mud were heated in an inert atmosphere in a bath of molten lead to drive off and recover the phosphorus for recovery. These stills were used to process the phosphorus residues recovered from the site. However, their throughput was limited to a few tons per week and large volumes of relatively mildly contaminated material was being generated and stored as the work progressed. Advantage was taken of phosphorus' propensity to fume at concentrations of 10ppm or less by spreading the generally clayey and fine grained materials in layers 150mm or so thick on the large concrete slabs on site. This was regularly worked over using agricultural tilling machinery and the phosphorus allowed to oxidise and 'fume off' naturally.

Oxidation

Whilst most of the phosphorus residues were found at the north end of the site in the disposal pits or under the 'hot' furnace and process areas, a significant pocket was found in the apparently otherwise 'clean' southern feedstock processing end of the site. This neatly encapsulates the problems and remedies adopted on site. When originally built, the intention was to 'pelletise' phosphate rock feedstock by mixing with clay. This proved to be inefficient and the concrete figure of eight shaped clay-mixing tanks became redundant. These were about 3m deep and embedded in the ground.

Pits dug into the tanks in the early investigations showed that they had been filled with 'type 1' crushed limestone with no apparent phosphorus residues. Indeed none were expected. However, when the time came to dig out the tanks, it became apparent that there was a large quantity of yellow phosphorus in the gravel backfill outside of the tanks. Indeed it could be described as 'phosphorus concrete'.

Phosphorus in ‘worm holes’

Further research with former employees revealed that, to deal with a minor crisis in the works, phosphorus had been put into the concrete tanks for temporary storage. When the time came for its removal, steam lances were used to melt the solidified phosphorus so that in due course it could be pumped out. However, when the pumps were turned on, mostly hot water came out. Several tonnes of phosphorus had ‘disappeared’. When molten at 60°C, phosphorus with its specific gravity of 2.7 and minimal surface tension has the penetrating power of ‘heavy’ WD40. It had clearly gone straight through the 150mm concrete walls to collect and solidify in the cooler gravel surround. On excavation it was also found to have penetrated into desiccation cracks and old worm and root holes in the alluvium as well as down the sides of foundation piles. This had also been seen under the old furnaces and was later found under the process house.

Phosphorus around piles

Other ‘escapes’ of phosphorus were found under some drain runs. Much water, both hot and cold, was used for obvious safety reasons to wash down equipment and floors during the life of the works. This went into the drainage system and ultimately to a treatment plant prior to discharge to the

estuary. Clearly, any phosphorus that collected in the drains could be melted by a flush of hot water to escape through joints or minor cracks down into the surrounding soils.

Indeed some of the purest phosphorus ever seen on the site was found in the drainage chambers where repeated melting and cooling had resulted in the accumulation of masses of white opalescent, waxy material. The term 'yellow' phosphorus is a misnomer as the colour is due to inclusions of fines carried over in the refining process.

After demolition of the last still, the verification process uncovered some residual phosphorus in the backfill in the process house area. This zone was originally cleared during a particularly wet period and this suppressed the usual fuming. Also, it became clear that the high purity of the phosphorus here meant that it tended to be 'passified' by a thin surface coating of oxides that inhibited the usual spontaneous combustion. Albright & Wilson took the decision to re-excavate the process area and significant quantities of low concentration contamination as well as pockets of pure phosphorus were found at depth. The lower grade material was oxidised on site whereas the particularly phosphorus rich deposits were drummed and sent for incineration.

The desk studies had revealed the presence of an oil refinery under the northern part of the site and indeed, hydrocarbon contamination was a problem for Albright & Wilson's early reprocessing work to recover phosphorus from the site.

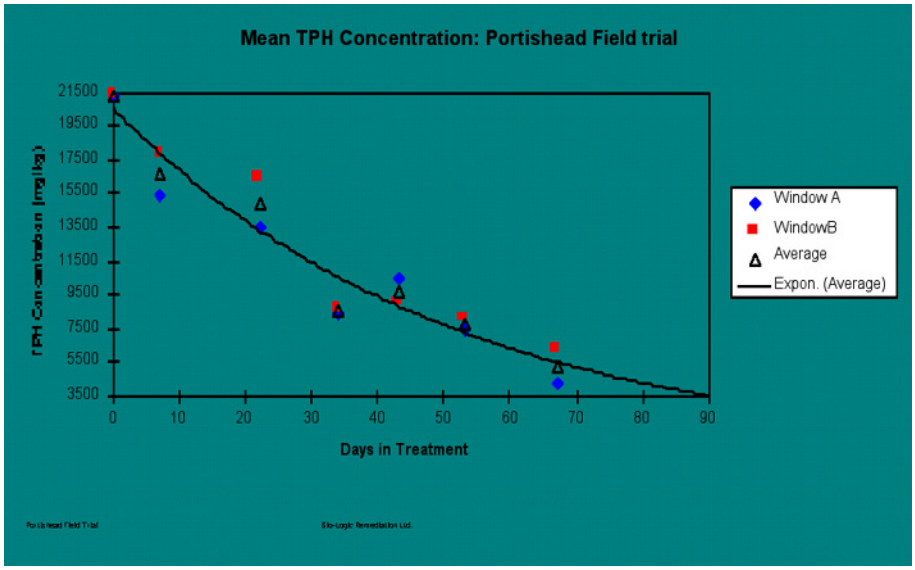
The 1995 site investigation works had uncovered crude oil contamination in some areas but the absence of oil sheens or other visible hydrocarbons in the large water filled pits which then occupied part of the northern site, appeared to support the notion that the oil contamination was of relatively limited extent. Provision was made in the schedules for site disposal of an estimated 25,000m³ of oily material. However, as the clearance work progressed into the former oil refinery, it became apparent that the volumes of contaminated material had been significantly underestimated as rubble and oil filled basements; tank pads and pipelines were uncovered. It also proved very difficult to limit cross-contamination when for example oil filled pipes embedded in apparently clean clay were broached.

Oil

Old pipework

Alternative methods of dealing with the hydrocarbons were investigated. BioLogic were invited to site to carry out a trial bioremediation. Two small windrows of oil contaminated, mainly ashy soil were set up, mixed with 'substrate' and treated with nutrients. These were monitored and the results showed a marked decrease in hydrocarbon content including the PAHs.

Results of bioremediation field trials



As this was a variation from the SDW, the Section 106 had to be amended and this became a complex issue for the legal advisors of the various parties to agree before the site work started.

After the successful trials and extensive discussions with the interested parties, particularly the University of Birmingham who NSC had appointed as advisors, the following criteria were agreed for allowing bioremediated material to be encapsulated in cells dug into the relatively impermeable alluvial clay.

(i) Total petroleum hydrocarbons (TPH) shall not exceed 3000mg/kg for 95% of samples and 5000mg/kg for 100% of samples.

(ii) Polynuclear aromatic hydrocarbons (PAH) shall not exceed 100mg/kg for 95% of samples and 150mg/kg for 100% of samples.

(iii) The concentration of any one of the 16 US Environment Protection Agency PAH compounds shall not exceed 50mg/kg with the exception of benzo[a]pyrene which shall not exceed 10mg/kg.

(iv) No remediated material to be above 6.5m AOD and to be capped with a minimum of 0.5m of clean alluvial clay.

Tenders were invited from the contractors for the excavation, bioremediation of encapsulation of the hydrocarbon contaminated material stockpiled to date and that still in the ground in the north. Detailed Method Statements were required from the contractors to demonstrate their understanding of the risks and issues and these too were the subject of considerable debate and amendments before and during the works. For example, there was concern that residual organic matter from the substrate, spent mushroom compost could give rise to problems due to landfill gas generation. However, analysis of samples from the windrows showed that the perceived amount of straw was considerably less that the actual weight proportion, was mainly relatively recalcitrant lignins etc and was no more than would be expected in the local natural alluvium.

The work was awarded to Churngold Remediation and BioLogic. They laid a stone blanket over the cleared and refilled ground. Coarse stone, concrete and metals were screened out of the stockfill for crushing or disposal. The fines and crushed materials were formed into windrows for treatment.

The work did not start until October 1998 and the winter weather made aerating the windows to encourage biodegradation difficult. The high proportion of clay in the soils meant that the heaps tended to warm up only slowly and intimate mixing of soil nutrients and substrate was difficult. Although sheeted, the heaps also absorbed water through their bases.

Once the bugs in the windrows were estimated to have reduced the hydrocarbon contents to below the ‘thresholds’, representative samples were recovered and sent away for analysis. It soon became apparent that the results were somewhat erratic with elevated PAHs in some but not in others. Careful examination of the materials revealed the presence of small discrete lumps of tarry material. This, due to their generally long chain and waxy molecules and limited surface area, were not responding to the bioremediation. However, by the same token, they did not represent a significant hazard to the environment and so the agreed ‘threshold’ values were relaxed to:

(i) TPH not more than 3000mg/kg.

(ii) PAH not more than 500mg/kg.

In addition and to confirm the ‘non-mobility’ of the material, one sample per windrow was subjected to an NRA type leachate test to show broad compliance with the Dutch intervention values for groundwater.

Following acceptance of test results; the contractor excavated cells up to 6m deep from a starting level of about 5.5mAOD and backfilled the treated material. It was originally intended to compact the soil in layers its low strength and high moisture content precluded the use of rollers and so it was simply ‘tracked in’ but the excavators. The top of the fill was, on average, about starting level and clay used to cap it off to about 7mAOD resulting in a average 1.5m thick cap.

Some of the slag and slag-rich excavated material was used as bulk fill in the core of a landscape and flood protection moved on the seaward side of the site and in a barrier built across the Portishead Ditch.

During the excavation works a small quantity of bagged asbestos was uncovered. Specialist contractors dealt this with. Also found were a few drums of resin formerly used to assemble the carbon electrodes with the electric arc furnaces. There were also four drums of a white powder that, on analysis, proved to be strontium sulphate. This was ground celestite the principal ore of strontium that was once extensively quarried around Yate, to the north of Bristol. How it came to be buried at Portishead is unknown.

In the refinery area were masses of tinplate offcuts from the petrol canning works that once operated here along with rails and sleepers from the freight lines. No cyanide, buried cranes or excavators were uncovered.

During the works a corridor across the north end of the site was not excavated as it carried live buried 132kVA cables. Some oil contamination appears to be extended beneath into the cable reserve and this can be investigated and treated now that the cables have been decommissioned.

Concrete and brickwork from the buildings and substructures and oversized excavated rubble were stockpiled on site for eventual crushing and use as oversite capping. However the material was first used to create an access mound to one side of the 30m tall concrete feedstock silos at the south end of the site. By gathering together all available rubble, the mound was first high enough to enable the contractor's long reach demolition shears to reach the roof of the silos.

Arup's role as Environmental Consultant included, amongst other things, monitoring the ongoing works to ensure that the aims and targets set out in the SDWs were achieved. In order to confirm, or otherwise, that the works had been done satisfactorily and as the remediation works neared completion, trial pits were dug around the site.

Also pockets of 'out of tolerance' hydrocarbon contaminated soils were found, usually with excessive PAHs, and removed. Some oily pipes dug into the alluvium were also found and chased out. Of more concern were areas where beneath an apparently clean layer of relatively structureless alluvial clay, hydrocarbons were found to have penetrated into the body of the clay via old root holes and desiccation cracks. These areas appear to coincide with placed where 'tins' of product can be seen to have been stockpiled on old photographs of the site. Apparently these containers were notoriously leaky. Some of these areas remain to be finally dealt with when the cable reserve is remediated.

For recording purposes the site was divided into 20m grids and the day-to-day activities set down using that as a reference. At the end of the main phase of works 'Final Decontamination Reports' were prepared for each zone. These contain 'grid sheets' for each square which outline the various activities undertaken there including dates of excavations, backfilling and sources of fill, tests etc. The reports also contain the method statements, agreed amendments, relevant correspondence, trial pit and laboratory test results and any other relevant information. As can be imagined, the reports each run to several substantial volumes and occupy about 300mmm of shelf space.

The decontamination works over the 11hectare site were undertaken essentially as an earthworks operation; i.e. remove overburden, sort, screen and crush, treat or remove phosphorus and oily materials and return to ground in sequence to achieve specified minimum depths of clean cover to all treated materials. A total of about 250,000m^3 were excavated and treated. Less than 2,000m^3 were removed from site.