CL:AIRE

CON 04
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Concawe bulletin

CL:AIRE's Concawe bulletins describe the deployment of sustainable remediation techniques and technologies on sites in Europe. Each bulletin includes a description of the project context and conceptual site model along with a sustainability assessment. This bulletin describes a solar powered pump to recover hydrocarbon contamination.

Sunshine on the Tyne – Sustainable Hydrocarbon Remediation

1. INTRODUCTION

The project comprised the remediation of free phase hydrocarbon present in an infilled below ground tank structure. The objective was to achieve permanent environmental betterment in a sustainable manner and minimise the risk to groundwater and surface water. A remedial solution was designed that used solar powered down-borehole pumps and operated over a period of 22 months. A total of 6,100 litres of hydrocarbon was recovered during this period.

2. SITE DESCRIPTION AND PROJECT CONTEXT

Northern Gas Networks (NGN) own and operate a gas holder station in Redheugh (Gateshead, northern England) occupying an area of 2.1 ha. The site is an operational natural gas distribution site featuring above ground pressure reduction infrastructure, a network of below ground utilities, and three decommissioned gas holders. The site is located within a wider mixed residential and industrial area.

The site has been a gas holder station since the 1890s, originally comprising four gas holder structures used to store town gas (manufactured gas). The historical site layout is shown on Figures 1 and 2.

Gas Holder No. 3 was demolished and the below ground tank infilled during the late 1980s/early 1990s. Several phases of ground investigation were undertaken to characterise the dimensions of the gas holder and the distribution of contamination within it. This included supplementary ground investigation by Sweco to further characterise the spatial distribution of dense non-aqueous phase liquid (DNAPL) hydrocarbon and install recovery wells for remediation. Ground investigation identified significant hydrocarbon contamination (dissolved and non-aqueous phases) in the infilled tank of former Gas Holder No. 3. The structure has a diameter of approximately 48 m with a masonry wall and base. The base of the tank is up to 9.5 metres below ground level (mbgl). The DNAPL hydrocarbon present within the gasholder tank was considered to be contained and hydraulically isolated from the surrounding strata (alluvium and glaciolacustrine deposits over glacial till), but given its

Figure 1: Redheugh Gasworks, 1939.

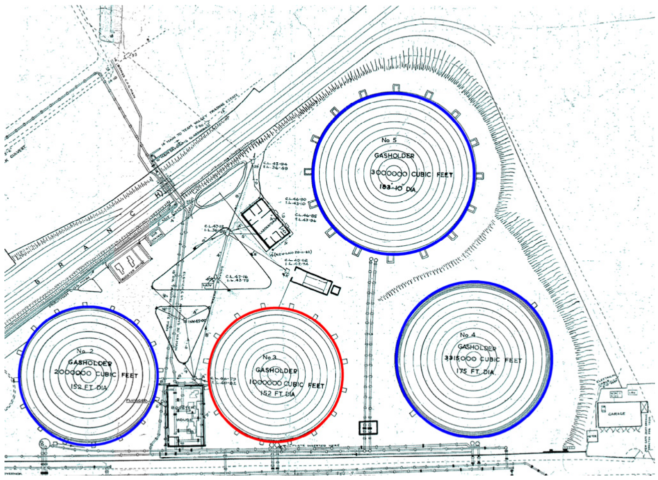

Figure 2: Extract from 1936 site layout plan showing the location of the four gas holders on site. Gas Holder No. 3 is the middle of the four gas holders shown and circled red. Gas Holders Nos 2, 4 and 5 are circled blue. Courtesy of National Gas Archive.

Concawe
Environmental Science for European Refining

For further information please contact the authors:
Neil Whalley, Northern Gas Networks, nwhalley@northerngas.co.uk
Emma King, Sweco UK Limited, emma.king@sweco.co.uk
Adam Wilson, Geo2 Remediation Limited, adam.wilson@geo2.co.uk

If you would like further information about other CL:AIRE publications please contact us at the Help Desk at www.claire.co.uk age, its integrity is expected to degrade to the point where this will no longer be the case in the future. NGN appointed Sweco to develop a remedial solution that would achieve environmental betterment by permanently reducing the quantity of DNAPL hydrocarbon and the associated risks posed to environmental receptors, including surrounding groundwater and surface waters.

Gas Holder Nos. 2, 4 and 5 were undergoing decontamination and dismantling during the Gas Holder No. 3 remediation project. The design of the remediation system (including the physical footprint occupied by equipment and frequency of maintenance visits) required liaison with the demolition contractor to ensure that the remediation works did not impact their programme.

The remedial solution comprised targeted DNAPL hydrocarbon recovery commencing with a 6 month pilot trial followed by full-scale operation of the remediation system (22 months in total).

Four self-contained remediation systems were deployed, each comprising a fenced compound which contained a 100 mm diameter, 9 m deep recovery well installed within Gas Holder No. 3 and associated remediation equipment. The location of the remediation system infrastructure is shown on Figure 3. The need for a small operational footprint was a key design consideration for the remediation system due to the space requirements for the gas holder demolition works being undertaken concurrently across the wider site. Each remediation system occupied an area of only 12 m^2.

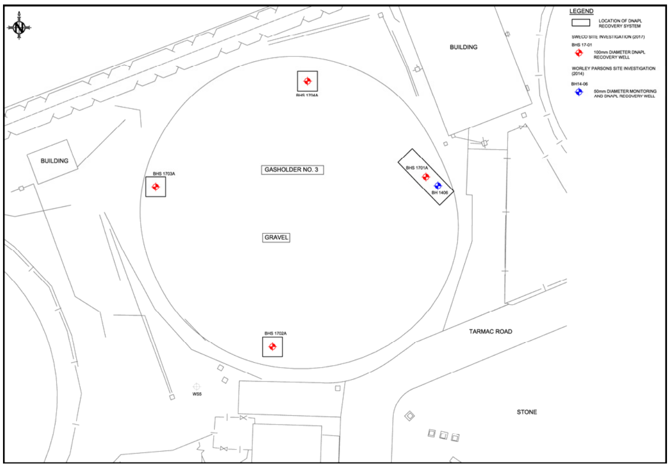

Figure 3: Remediation system layout.

The remediation systems each comprised a bottom loading pneumatic pump which recovered DNAPL hydrocarbon and contaminated water from the well into intermediate bulk containers stored within constructed bunded areas. Each pneumatic pump was powered by an individual receiver compressor connected to a battery and a timer/controller unit. The battery was charged via a 100 W photoelectric solar panel (only) thereby providing a solely renewable energy source. This was an important design aspect as there was no readily accessible electrical supply on the site. Examples of similar solar powered remediation systems in the UK are rare. Each pumping system could be set at user defined intervals to suit the recovery characteristics of each well and the DNAPL hydrocarbon being recovered at that location, whilst also balancing the power requirements from the battery. The treatment systems operated remotely without the requirement for permanent supervision. The remediation system at BHS17-04A is shown in Figure 4.

Figure 4: Remediation system at BHS17-04A.

3. CONCEPTUAL SITE MODEL

A conceptual site model is provided as Figure 5.

Several phases of ground investigation confirmed that the in-ground gas holder tank structure of Gas Holder No. 3 has a diameter of approximately 48 m with a masonry wall and base. The base of the tank is approximately 5.7 mbgl in the centre and 9.5 mbgl in the annulus (immediately inside the tank wall). Fill materials within the holder tank typically comprised made ground of clayey gravel to gravelly clay with some tarmacadam, plastic, wood, glass and metal. The in-ground tank contains water resting at between 0.2 mbgl and 0.5 mbgl.

Monitoring wells installed into the gas holder tank identified that DNAPL hydrocarbon in the form of coal tar/creosote is present within the base of the tank. DNAPL hydrocarbon was identified in all monitoring wells installed around the annulus of the tank, with thicknesses ranging between 0.12 m and 1.8 m.

Outside the tank structure, surrounding ground conditions typically comprise made ground of reworked natural material up to c.6 m deep overlying principally gravelly clay superficial deposits of alluvium and glaciolacustrine deposits identified to at least 23 mbgl (base unproven). The solid geology beneath the site comprises the Pennine Middle Coal Measures. The alluvium is classified by the Environment Agency as a Secondary A Aquifer and the

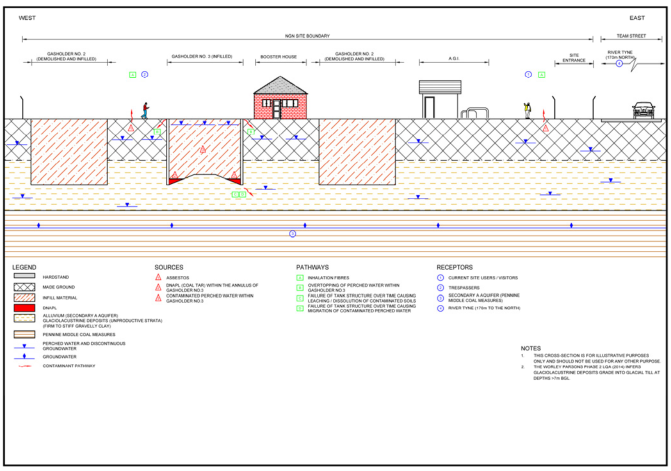

Figure 5: Conceptual site model.

glaciolacustrine deposits as Unproductive Strata. Perched groundwater was identified in the superficial deposits with no laterally continuous groundwater body identified. The Pennine Middle Coal Measures are classified by the Environment Agency as a Secondary A Aquifer. Surface watercourses are present within 200 m of the site.

The site environmental risk assessment identified that the hydrocarbon is substantially contained by the former tank structure of Gas Holder No. 3 and is considered to be hydraulically isolated from the water within the surrounding ground. As such, the contamination within the gas holder tank is not considered to pose a significant risk to environmental receptors under current site conditions and usage. However, it was noted that this assessment could change in the event of degradation of the in-ground former gas holder tank wall with potential for contaminant release and pollution of controlled waters.

4. ASSESSMENT FUNCTION

The assessment of the study site was undertaken through a tiered approach comprising several phases of ground investigation, with refinement of the conceptual site model after each phase to build up an understanding of the pollutant linkages and associated levels of risk. This approach ensured that the assessment was proportionate and robust. The contaminant linkages which were the focus of the project were those relating to controlled waters receptors (groundwater and surface water) and the potential migration of contamination from Gas Holder No. 3 to impact them. Whilst not considered to pose a potential statutory liability in its current condition, the hydrocarbon contamination (dissolved and non-aqueous phases) within the gasholder tank and the potential to cause pollution of controlled waters in the future was the driver for remediation. In line with NGN's Environment Strategy (that includes five main focus areas linked to United Nations Sustainable Development Goals and targeted at reducing NGN's environmental impact, with land remediation commitments covered under 'Improve Life on Land' aligned to Goal 15), the objective was to mitigate future risks associated with degradation of the below ground structure and achieve permanent environmental betterment in a sustainable manner.

5. SUSTAINABILITY ASSESSMENT

A sustainability assessment was undertaken following the approach set out in BS ISO 18504:2017 (ISO, 2017). This approach enabled the project team to identify the optimum methodology to achieve the remediation objective whilst adapting to the following identified site aspects:

- Limited space for remediation equipment due to ongoing large-scale demolition across the wider site;
- No readily accessible electrical supply or drainage within the works area on-site;
- NGN safety restrictions on 'live' gas sites precluded telemetry to remotely monitor remediation equipment;
- Constrained vehicle access to the site; and
- Wider mixed residential and industrial setting which is sensitive to vehicle movements, noise, dust and odours.

Stakeholder Mapping

A mapping exercise was undertaken to identify relevant project stakeholders and their sustainability goals for the duration of the remediation project. The outcome of the stakeholder mapping is presented in Table 1.

Table 1: Stakeholder mapping.

Project Vision: *Achieve voluntary environmental betterment by permanently reducing the quantity of DNAPL hydrocarbon present and the associated risks posed to environmental receptors, whilst still allowing the site infrastructure to operate*							
Project Boundary: *Whole life, including capital and operational expenditure and impacts*							
Stakeholder Goals	*Equivalent SuRF-UK headline sustainability indicator (CL:AIRE, 2020a,b)*	Stakeholders					
		S1. NGN (client and site owner)	S2. Site users (NGN operations)	S3. Site users (gas holder demolition contractor)	S4. Site neighbours (residential)	S5. Site neighbours (commercial)	S6. Environmental regulators (local authority and Environment Agency)
Environmental Goals							
Achieve permanent environmental betterment (Env1)	*ENV2* *ENV3*	✓			✓		✓
Minimise whole-life project environmental impact (Env2)	*ENV1* *ENV5*	✓					
Social Goals							
Minimal impacts on site neighbours / residents (Soc1)	*SOC1* *SOC3*	✓		✓	✓	✓	✓
Economic Goals							
Minimal impacts on wider site activities (Eco1)	*ECON2*	✓	✓	✓			
Affordable whole-life project cost (Eco2)	*ECON1*	✓					

This process enabled the identification of five main project goals informed by project stakeholder priorities against which relevant project specific sustainable remediation objectives, indicators and metrics could be established to directly inform the remediation options sustainability assessment, and also identify material remediation performance criteria for use in verification reporting. These are summarised in Table 2.

Semi-Quantitative Remediation Options Sustainability Assessment

Semi-quantitative sustainability assessment of each potential remediation option was undertaken by assigning scores to each objective. This process ensured that the remediation options sustainability assessment identified the optimum solution to consciously achieve both the project vision and stakeholder goals. The assessment is presented in Table 3.

Table 2: Sustainable remediation objectives, indicators and metrics.

Project Goals (Stakeholders Goals / Relevant Stakeholders)	Sustainability Category and equivalent SuRF-UK headline sustainability indicator (CL:AIRE, 2020a,b)	Project Objectives*	Project Indicators	Project Metrics
Goal 1 (Env1) Achieve permanent environmental betterment (S1, S4, S6)	Environmental *ENV2* *ENV3*	1A. Permanently remove environmental risks associated with DNAPL hydrocarbon contamination inside Gas Holder 3	1A-1. Quantity of DNAPL Removed 1A-2. Thickness of DNAPL remaining	Litres removed Metres as measured in monitoring wells
Goal 2 (Env2) Minimise whole-life project environmental impact (S1)	*ENV1* *ENV5*	2A. Minimise waste generation	2A-1. Quantity of waste removed from site	Litres/tonnes removed
		2B. Minimise resource consumption	2B-1. Quantity of imported backfill material required	Tonnes
		2C. Minimise greenhouse gas emissions	2C-1. Operational emissions of greenhouse gases (equipment and transport fuel consumption)	tCO2e
Goal 3 (Soc1) Minimal impacts on site neighbours/ residents (S1, S3, S4, S5, S6)	Social *SOC1* *SOC3*	3A. Minimise local air quality impacts	3A-1. Project vehicle movements 3A-2. Project equipment fossil fuel consumption	Litres of fossil fuel consumed
		3B. Minimise noise impacts	3B-1. Noise rating of project machinery/equipment	dB
		3C. Minimise dust and odour impacts	3C-1. Site neighbour complaints	Number of attributable complaints received
Goal 4 (Eco1) Minimal impacts on wider site activities (S1, S2, S3)	Economic *ECON2*	4A. No constraints to operation of gas infrastructure at any time	4A-1. Complaints / issues from NGN Operations	Number of complaints received from NGN Operations
		4B. No significant constraints on wider gas holder demolition project	4B-1. Complaints / issues from demolition project team	Number of complaints received from demolition team
Goal 5 (Eco2) Affordable whole-life project cost (S1)	*ECON1*	5A. Minimise whole-life project cost	5A-1. Whole-life project cost	Total project cost (capital and operational - £ excluding VAT)

*Note that minimising health and safety performance was not included as a specific project objective as this is core to all NGN projects.

Table 3: Semi-quantitative remediation options sustainability assessment.

Potential Remediation Option	*Project Objectives / Category (equivalent SuRF-UK headline sustainability indicator (CL:AIRE, 2020a,b))*										*Total Score*	*Comments*
	Environmental (ENV1, 2, 3 and 5)				*Social (SOC1 and 3)*			*Economic (ECON1 and 2)*				
	1A	*2A*	*2B*	*2C*	*3A*	*3B*	*3C*	*4A*	*4B*	*5A*		
Do nothing (baseline assessment position)	1 *Fail*	3	3	3	3	3	3	3	3	3	*28*	Disregarded as objective 1A (permanent environmental betterment) not achieved.
Entire source excavation, disposal and backfill. (Includes dewatering and disposal of liquids off-site.)	3	1	1	1	1	1	1	1	1	1	*12*	Robust methodology enabling thorough contaminant removal but resource, waste, carbon and financially intensive. Social impacts anticipated.
Dewater tank of all liquids, dispose off-site and install low permeability cap to tank (such as clay or asphalt). (Includes drilling of boreholes to facilitate dewatering.)	2	2	2	2	2	2	2	2	2	2	*20*	Targeted waste removal with potential for some residual/ relcalcitrant contamination to remain, some resource requirement and some social impacts.
Targeted DNAPL removal using low energy system. (Includes drilling of boreholes to facilitate DNAPL hydrocarbon recovery.)	2	3	3	3	3	3	3	3	3	3	*29**	Targeted treatment to permanently remove only the necessary contamination with potential for some residual/ relcalcitrant contamination to remain. Minimisation of social and environmental impacts and costs.

*Potential remediation options were assessed against the baseline position of do nothing and assigned a 1 (poor) to 3 (good) rating of effectiveness or environment/social/economic impact (with reference to BS ISO 18504:2017, Section 7.4.3). Scores were then summed across all project objectives, with the most sustainable project remediation option being the highest scorer (as denoted by *).*

The remediation options sustainability assessment identified the optimum solution to achieve both the project vision and stakeholder goals to be targeted DNAPL removal utilising a low energy system fuelled by renewable energy. This option was deployed successfully as part of the project. This assessment provided the project team with a suite of project metrics against which the success of the project could be assessed.

6. PROJECT HIGHLIGHTS

NGN appointed Sweco to develop a remediation solution which would achieve the remediation objective whilst working around the site aspects and constraints. The remedial solution overcame site constraints and delivered a sustainable system which achieved permanent environmental betterment using only renewable energy to power remediation equipment with no significant impact on wider site activities or site neighbours.

Sweco undertook supplementary ground investigation to further characterise the spatial distribution of DNAPL and installed recovery wells for remediation. This informed the selection of potential remedial options which were subject to sustainability assessment to support the selection of the optimum solution. Assessment of site aspects, environmental, social and economic factors during the design process led to the development of a wholly sustainable, durable and robust remediation methodology. A 6 month remediation pilot trial provided an estimate of the potential DNAPL volume present and assessed the feasibility of consistently and robustly recovering DNAPL using pneumatic pumps installed in the recovery wells powered only by on-site renewable energy generation. The remediation pilot trial confirmed the presence of significant quantities of DNAPL which could be freely recovered from monitoring wells installed within the former holder tank by *in situ* pumping techniques.

Following the remediation pilot trial, Sweco were commissioned by NGN to undertake full-scale operation of the remediation system, with a total operating period of 22 months during which time 6,100 litres of DNAPL was recovered. Operation ceased when recovery rates reduced to a level where continued operation was no longer considered beneficial in removing the contaminant source. The volume of DNAPL recovered and the rate of recovery were monitored during the operational phase to enable system optimisation and to measure the effectiveness of the remediation activities.

This low intensity renewable energy driven approach designed by Sweco and their contractor Geo2 Remediation Ltd provided multiple economic, social and environmental benefits as summarised in Table 4.

Table 4: Economic, social and environmental benefits.

Remediation System Feature	Environmental Benefit	Social Benefit	Economic Benefit
Use of entirely renewable energy source	Carbon savings and air quality benefits compared to use of electricity from mains or on-site generators. Four individual petrol powered generators to enable the same operation would have generated 61 tonnes of CO_2 equivalent, the same as the emissions from an average car driving 207,000 miles. Carbon saved has monetised societal value of £4,000.	Minimal impact on site neighbours with no complaints received during operation. Quiet system compared to use of traditional on-site generators. Alternative required four individual petrol powered generators for 50 hours per week each rated at 94 dB. No air quality impacts from emissions from generators or equipment.	No operational energy costs. Four individual petrol powered generators would have cost approx. £25,000 more in equipment and fuel than the solar power solution used.
In situ remediation targeting DNAPL	Waste generation minimised by targeted recovery of DNAPL. Vehicle movements associated with waste disposal minimised thereby limiting carbon and air quality emissions.	No significant odours, noise or dust during operation. Vehicle movements associated with waste disposal and associated nuisance and vehicle emissions minimised.	Waste disposal costs optimised.
Remote operation with minimal maintenance requirements	Monthly maintenance visits required only, thereby limiting carbon and air quality emissions from vehicles.	Vehicle movements associated with maintenance visits, and associated nuisance and vehicle emissions minimised.	Minimal maintenance costs (mechanically simple).

7. LESSONS LEARNED

This project demonstrates how a sustainable, low intensity remediation technique can be applied to remediate free phase hydrocarbon (Light Non-Aqueous Phase Liquid (LNAPL) or DNAPL) contamination in soil.

The remediation system at Redheugh Holder Station successfully recovered 6,100 litres of DNAPL during the 22 months of operation, powered solely by solar energy whilst having no significant impact on wider site activities or site neighbours. Whilst the operational interval of the remediation equipment had to be balanced against power generation from the solar panels, this project demonstrated it to be a successful approach to deploy on sites where the physical characteristics of DNAPL being removed require a slow sustained rate of recovery, and where there are no specific remediation time constraints such as in a development programme.

8. CONCLUSIONS

The remediation strategy that was developed provided permanent sustainable environmental betterment using technology powered only by renewable energy, examples of which are rare in the UK. There are numerous other situations in which this technique could be operated to deliver sustainable environmental betterment, including the remediation of remote or off-grid sites.

REFERENCES

- CL:AIRE. 2020a. Supplementary Report 1 of the SuRF-UK Framework: A general approach to sustainability assessment for use in achieving sustainable remediation.
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