Argentum Fox

Barnageeragh

Attention: **Padraic Mulroy**
Managing Director

25th February 2019
AF7051

Mulroy Environmental
30 Lisroland View
Knockbridge
Dundalk
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Eire

Dear Padraic

Peer Review of gas and vapour risk to houses, and groundwater at Barnageeragh development

Argentum Fox is pleased to provide an independent peer review of work associated with gas, vapour and groundwater issues and the historic waste deposit at the above-mentioned site.

Background understanding

An historical waste deposit is present to the south of the new houses on-site. Extensive field work and subsequent assessment of the environmental data has been undertaken on both the waste deposit and houses themselves up to and including January 2019. Mulroy Environmental need to assess the robustness of their conclusions with respect to potential gas and vapour intrusion into the houses and potential impact to groundwater and surface waters.

Reports reviewed

Reports reviewed in detail:

A. Phase II Site Investigation/GQRA & Landfill Gas Survey, Interim Gas Monitoring Report, 2nd July 2018. Report 308-1
B. RBCA model file 'RBCA with Soil VOC data29.08.18.xlsx'
C. Detailed Quantitative Risk Assessment of Barnageeragh Cove Landfill Rev D. Response to Queries Plus Preferred Cap Design, Prepared by: Peter Conroy, January 2019
D. Gas data up to and including 21.1.2019 Skerries Residential Gas Monitoring Results.pdf, 21.1.2019 Skerries Borehole Gas Monitoring Results.pdf
E. Historic Landfill Skerries - Prelim Technical Proposal for Capping DRAFT AGL (7 12 2018) (003).pdf

Reports read for background information but not peer-reviewed:

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1. Phase II Site Investigation/GQRA & Landfill Gas Survey, Interim Report. 277.29.08.17. 29th August 2017. Mulroy Environmental.
2. AGL17283_01. Report on The Geophysical Investigation at Barnageeragh Cove Landfill, Co. Dublin, 21st December 2017. Apex Geoservices Ltd
3. AGL18018_01. Report on the Phase 1 & Phase 2 Geophysical Investigation at Barnageeragh Cove Landfill, Co. Dublin. 09th February 2018. Apex Geoservices Ltd.
4. Occupational Monitoring of Headspace Air Within House No. 25, 26, 52 & 53 and Headspace Monitoring of Gas Well 1, Gas Well 2, Gas Well 3, and Gas Well 4 located in Barnageeragh Cove, Skerries, Co. Dublin. Performed by Odour Monitoring Ireland. 12th June 2018 Ver.4. Report Number: 2018014(4)
5. Occupational Monitoring of Headspace Air Within House No. 47, Barnageeragh Cove, Skerries, Co. Dublin. Performed by Odour Monitoring Ireland. 24th July 2018 Ver.1. Report Number: 2018356(1)
6. Phase II Site Investigation/DQRA & Landfill Gas Survey, Final Report 309-01. 31st August 2018. Mulroy Environmental.
7. Groundwater Results Borehole Sampling 17.07.18.xls
8. Draft Soil Results 13.03.18.xls
9. Email from RPS 'Interim Landfill Gas Monitoring Results (Ref 308-01) dated 2/7/18'. Mortimer Loftus to Padraic Mulroy
10. Gas Analysis of Headspace Air within gas sampling bag containing frost protection cap from House 26 and 52, Barnageeragh Cove, Skerries, Co. Dublin. OMI 31st January 2019
11. Phase II Site Investigation/DQRA & Landfill Gas Survey, Final Report 309-02. 31st January 2019. Mulroy Environmental.

Conceptual Site Model

The conceptual model identified three key potential source-pathway-receptor linkages for the purposes of this peer review:

A. Landfill gas potentially migrating from the former waste deposit through Made Ground or silty gravelly SAND indigenous soil to the housing to the north of the waste mass;
B. Groundwater contaminated by the waste deposit flowing north from the waste mass with possible volatilisation into the unsaturated zone beneath the houses; and;
C. Contaminated groundwater flow north, northeast, and south from the waste deposit.

Contaminant linkages 'direct contact' and 'ingestion' associated with the deposited waste were assessed as incomplete by Report 1, noted above. This is a reasonable assessment since the waste deposit will be buried beneath a clean cover layer (Historic Landfill Skerries - Prelim Technical Proposal for Capping DRAFT AGL (7 12 2018) (003).pdf).

Potential Linkage A – Landfill Gas

In terms of the potential source of landfill gas, the waste deposit and surrounding soils have been extensively characterised by 50 trial pits (Report 1), Geophysical investigation (Reports 2, and 3), and installation of 17 groundwater and gas and 4 shallow gas monitoring wells. At intrusive investigation locations, soil sampling has been undertaken to characterise the waste (Report 1). The monitoring wells (apart from the three installed in 2018) have subsequently been tested on a regular basis for nearly 18 months (Report D).

The lateral and vertical extent of the waste has been well constrained by geophysics and intrusive excavation. The waste composition has also been well constrained, with two predominant waste types identified (Report C). Most Total Organic Carbon (TOC) concentrations are below 3%, with some below 5% and occasional detections above 5% (Report 1). This is a line of evidence that backs up visual observations from the trial pits and boreholes (Report1) that there is limited putrescible organic matter in the waste deposit from which to generate gas.

In the general conceptual model of landfill gas migration, gas is generated within the waste; it then a) pushes out the air that is entrained within the pore-spaces; and then b) moves along the path of least resistance via advection and/or diffusion to areas of low pressure and/or low concentration, respectively.

In monitoring rounds to date (Report D), the balance gas (inert nitrogen in the soil pore-spaces) is similar to atmospheric air concentrations in almost all wells, indicating that there is insufficient gas generation to push out the air entrained and diffusing into the unsaturated zone. This is another line of evidence that there is limited putrescible organic matter in the waste deposit from which to generate gas.

The only location where the balance gas concentration is less than atmospheric air is BH4. Even here the gas generation rate is not sufficient to remove all the gas diffusing into the subsurface, as it would in a normal landfill. The long term trends in gas composition in BH4 indicates the methane in BH4 is seasonal. In the summer months the putrescible material either dries out, reducing gas generation, or air can more easily diffuse into the subsurface reducing anaerobic degradation. In the winter months the waste material becomes wet and starts generating gas again, or the amount of air diffusing into the subsurface is reduced.

In a typical landfill gas migration investigation, wells would be placed within the waste and then within the pathway from the waste to the receptor. Only if gas was found in the pathway would receptor point monitoring be undertaken. This was the approach followed in Report A.

Wells BH1, BH2, BH3, BH5, BH6, and BH7 are placed within the waste mass. Gas generation is insufficient to remove the balance gas from the pore spaces within the waste, although at BH6 and BH7 there is a correlation with rising atmospheric pressure and decreasing methane. Landfill gas concentrations at old landfills typically increase after rainfall has sealed the ground surface, with gas subsequently accumulating before a low-pressure weather front passes over the landfill drawing out the gas. During periods of high pressure, the ground dries up and there is no driver for advective flow from the ground. Post venting well installation data indicates that 7 of the 21 are very low risk (GS01-04, BH2, BH3 and BH5). The rest are 'low risk'

The most recent guidance following the CIRIA 665 Gas Screening Value (GSV) methodology as used in Report A is BS8485:2015 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'. This document suggests that a number of other factors need to be considered:

> *6.3.7.1 General*
> *The designation of GSV should be made by inspection of all the data based on the conceptual site model for the situation with the development's sub-structure and foundations in place.*
> *NOTE 1 Adopting a GSV based on Qhg calculated from peak flow measurements might result in a disproportionately high gas hazard prediction, and assignment of an over-precautionary CS.*
> *NOTE 2 Examples of how monitoring data is considered to derive a GSV are given in Annex E. Where a development is to be built directly on or very close to the source of gas, then the Qhg adopted as the site or zone GSV should be based on gas measurements of the source. For a development off-set from a source, an assessment of the degree of hazard reduction afforded by the pathway between the source and the receptor should be made.*
> *NOTE 3 If the source has been monitored and is at some distance off-set from the development, then selection of the GSV based on an application of the Qhg obtained from the source is inappropriate.*

The only gas generating source material with the ability to displace nitrogen and therefore migrate via advective flow appears to be at BH4, estimated to be some 40m from the nearest house. No assessment of the degree of hazard reduction afforded by the pathway has been made as per Note 2, which is a conservative, worst-case approach. An assessment of hazard reduction afforded by the uncovered sub-soil pathway, with gas free to vent to surface, could potentially lead to the downgrading of all the risk associated with all boreholes to 'very low'.

Wells have then been placed within the pathway between the waste deposit and the houses to the north to investigate gas migration within this potential pathway (GS1 - GS4, BH4, BH8 – BH17). Of the boreholes in this potential pathway, Gas Wells GS1 - GS4, closest to the houses to the north, have been assessed as very low risk both before and after passive venting wells were installed (Report A, Tables 4 and 6).

Monitoring wells BH4 (and BH9 in close proximity) occasionally contain pockets of gas, but have nevertheless been characterised as being low risk (Report A, Tables 4 and 6). As noted, BH4 is the only well were gas generation has pushed some of the gas out of the porespace (the balance gas concentration is less than atmospheric). As also noted, gas concentrations in this well reduced after the septic tank associated with the builder's yard was removed in December 2017. Close to BH4 and BH9, wells BH8, BH10, BH11, BH12 contained elevated methane concentrations initially, which subsequently decreased. In January 2019, wells BH1, BH4, BH6, BH7, and BH17 contained some methane.

Monitoring wells BH8, and BH10 – BH17 have generally been characterised as low risk on a worst-case basis, which use the highest concentrations and flows during the monitoring period.

It is worth emphasising that no gas screening values in any of the 18 boreholes were above the very low risk threshold of <0.07 Litres per hour. Gas screening values are based on concentration and gas flow, which are linked to gas generation and gas migration rates. The only reason that the 'very low risk' assessment has been increased to 'low risk' for some wells is that the additional 'concentration only' thresholds of 5.0% for carbon dioxide and/or 1.0% for methane have been exceeded in those wells. This is a conservative approach to account for potential occasions that have not been monitored when gas flows may have been higher.

The potential gas migration pathways to houses to the west (BH2 and BH5) and the wastewater treatment plant to the east (BH12, BH15 - BH17) have also been assessed as low risk by the current monitoring well network, even though these potential receptors are further from the waste deposit.

Even though the risk has been assessed as very low risk in pathway boreholes, further gas monitoring has been undertaken within the houses and utilities next the houses where gas may flow along preferential pathways such as the gravel surrounding the utilities. This receptor point monitoring is a further precautionary measure. The monitoring determined that methane was absent or present at trace* concentrations within the radon sumps and where the water supply entered the base of the house. Carbon dioxide, which is present in natural soils, was detected at trace* concentrations with one elevated reading of 1.2% on the 11th June 2018 (Table 2, Report A). These data support the findings of the risk assessment and indicate that risks posed by gas from the waste deposit are low.

*Trace Detections for the purposes of this section are defined as the detection limit of the instrument x 5. The accuracy of trace detections should not be relied upon, because they may be caused by factors such as background interference by moisture in the gas (the analyser will have been calibrated using dry gas), or instrument drift as the instrument has warmed up or been moved since the latest calibration. These factors will affect portable instruments measuring methane, carbon dioxide, carbon monoxide, hydrogen sulphide and volatile organic compounds by photo ionisation detection (PID).

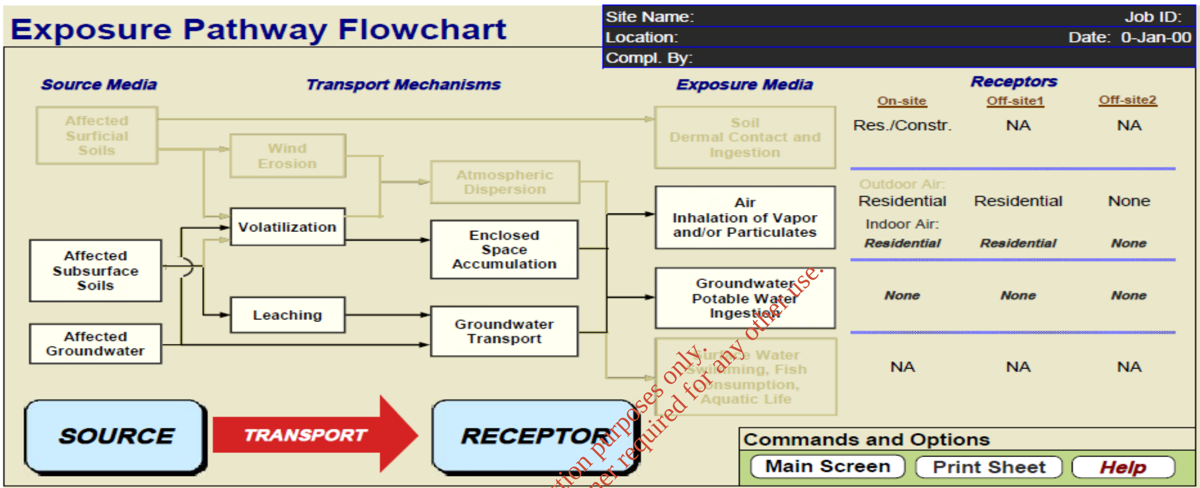
NOTE: Pre-field survey and post-field survey calibrations have been carried out on the GA5000 gas analyser using on-site calibration gas containing methane, carbon dioxide, sulphide and carbon monoxide. Similarly, pre and post sampling calibration of the PID has been done using isobutylene. Calibration records have been saved and are available for scrutiny.

Potential Linkage B – Contaminant Volatilisation from Soil or Groundwater

A total of 35 groundwater samples have been taken across three monitoring rounds (Report 5) from 14 groundwater monitoring wells. No VOCs were detected within the groundwater above the method detection limit in any of these samples. The potential pathway of volatilisation from tested groundwater into the houses is therefore incomplete.

Five soil samples were analysed for VOCs. Only two VOCs, namely vinyl chloride and 1,2-dichloroethane were detected in one soil sample (SO-TP21-01). It should be noted that this sample was taken from a trial pit located 51m from the nearest residence.

Regardless of the lack of detections of VOCs in groundwater, there is a possibility that the detected concentrations of mercury and volatile organic compounds could a) volatilise into outdoor or indoor air, or b) dissolve in groundwater, then volatilise into outdoor air or indoor air downgradient. To asses this pathway, the Risk Based Corrective Action model (RBCA) was used to assess whether the soil detections pose any risk to receptors indoors or outdoors.



The soils data have been entered for potentially volatile contaminants, with the input data summarised below. Note that the model, as a conservative assumption, assigns non-detect results the value of half the detection limit for the purposes of the statistical assessment.

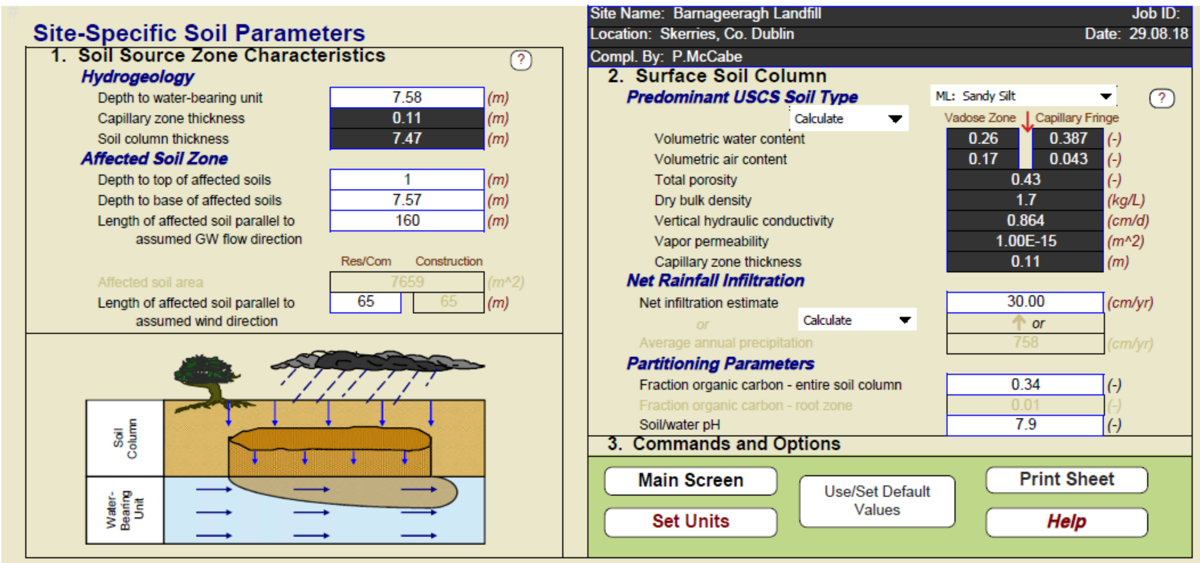
RBCA SITE ASSESSMENT

Site Name: Barnageeragh Landfill
Site Location: Skerries, Co. Dublin
Completed By: P.McCabe
Date Completed: 29.08.18
1 of 1

TIER 2 SOIL CONCENTRATION DATA SUMMARY

CONSTITUENTS DETECTED		Analytical Method			Detected Concentrations		
CAS No.	Name	Typical Detection Limit (mg/kg)	No. of Samples	No. of Detects	Maximum Conc. (mg/kg)	Mean Conc. (mg/kg)	UCL on Mean Conc. (mg/kg)
7440-38-2	Arsenic	2.0E+00	39	39	6.1E+01	2.6E+01	2.9E+01
7439-97-6	Mercury	1.0E-01	39	39	8.0E-01	2.9E-01	3.4E-01
7440-66-6	Zinc	2.0E+00	39	39	3.6E+03	5.3E+02	7.0E+02
7439-92-1	Lead (inorganic)	2.0E+00	39	39	1.7E+03	2.9E+02	3.9E+02
T-al2134	TPH - Aliph >C21-C34	1.0E+00	39	39	8.1E+02	9.8E+01	1.5E+02
T-ar2134	TPH - Arom >C21-C35	1.0E+00	39	39	1.2E+03	8.0E+01	1.4E+02
75-01-4	Vinyl chloride	1.0E-03	39	39	2.1E-03	1.0E-03	1.1E-03

Using default parameters for residential end-use, outdoor air concentrations above the waste deposit and indoor air concentrations 5m from the waste deposit were modelled as worst-case assumptions. The soil parameters modelled were for a sandy silt, which is a reasonable assumption given the silty gravelly SAND indigenous soils.



The calculated risk from all exposure pathways in the RBCA model is then assessed in comparison with a Hazard Index (HI). Anything over a HI of 1 requires further assessment or mitigation. The results of the RBCA model adding up all of the exposure pathways indicate the HI is over two orders of magnitude lower i.e., 100 times less, than a HI of 1.

RBCA SITE ASSESSMENT — **Baseline Risk Summary-All Pathways**

Site Name: Barnageeragh Landfill — Completed By: P.McCabe
Site Location: Skerries, Co. Dublin — Date Completed: 29.08.18 — 1 of 1

BASELINE RISK SUMMARY TABLE

EXPOSURE PATHWAY	BASELINE CARCINOGENIC RISK: Individual COC Risk – Maximum Value	Individual COC Risk – Target Risk	Cumulative COC Risk – Total Value	Cumulative COC Risk – Target Risk	Risk Limit(s) Exceeded?	BASELINE TOXIC EFFECTS: Hazard Quotient – Maximum Value	Hazard Quotient – Applicable Limit	Hazard Index – Total Value	Hazard Index – Applicable Limit	Toxicity Limit(s) Exceeded?
OUTDOOR AIR EXPOSURE PATHWAYS										
□	6.3E-10	1.0E-5	6.3E-10	1.0E-5	□	9.4E-4	1.0E+0	9.4E-4	1.0E+0	□
INDOOR AIR EXPOSURE PATHWAYS										
□	2.4E-8	1.0E-5	2.4E-8	1.0E-5	□	3.3E-3	1.0E+0	3.4E-3	1.0E+0	□
SOIL EXPOSURE PATHWAYS										
□	6.5E-7	1.0E-5	6.5E-7	1.0E-5	□	NC	1.0E+0	NC	1.0E+0	□
GROUNDWATER EXPOSURE PATHWAYS										
□	NA	NA	NA	NA	□	NA	NA	NA	NA	□
SURFACE WATER EXPOSURE PATHWAYS										
□	NA	NA	NA	NA	□	NA	NA	NA	NA	□
CRITICAL EXPOSURE PATHWAY (Maximum Values From Complete Pathways)										
	6.5E-7	*1.0E-5*	*6.5E-7*	*1.0E-5*	□	*3.3E-3*	*1.0E+0*	*3.4E-3*	*1.0E+0*	□
	Soil		*Soil*			*Indoor Air*		*Indoor Air*		

As a further precautionary approach, receptor point monitoring has been undertaken by two organisations. A general screen for Volatile Organic Compounds (VOCs) has been done by Mulroy Environmental as part of the gas monitoring regime (Report A). In addition, Odour Monitoring Ireland has undertaken diffusive sampling to identify specific compounds in the new houses (Reports 4 & 5). Actual measurement is typically more robust than modelling.

In terms of VOC monitoring in source and pathway monitoring wells GS1 – GS4, after initial well installation and the August 2017 monitoring, there have been no above trace detection VOC measurements (Report A). Initial elevated readings have been interpreted to be due to plasticizers in the new well pipework. Notably, the VOC concentrations in BH4, the only well indicating some gas generation, were below detection limit.

There have been no detections of VOCs above trace concentrations (that may be related to moisture or instrument drift during operation) beneath the houses in the radon sumps and foul sewers. However, there have been some trace concentrations of VOCs measured within the radon sumps within the houses (on the 1st October 2018, 26th November 2018 and on the 3rd December 2018) which likely can be attributed to moisture or instrument drift during operation of the photo-ionisation detector. The VOCs detected during the indoor monitoring could easily be from materials used in house construction/interior decorating or ambient air (see discussion below). The detection of these VOCs do not indicate that there is a linkage between the waste body and the residences.

Report 4 identified a number of volatile compounds in air within the houses, although the compounds detected are also associated with paints glues and background vehicle emissions. There was a noticeable odour of paints, varnishes and glues in the houses, and evidence of rubber cement tubes on the ground. In addition, benzene and toluene were detected in the travel blanks at various times. Dichloromethane and other chlorinated compounds have been 'blank corrected' by the laboratory, which also suggests background contamination at the laboratory from these compounds. No tubing blanks from well samples or background ambient air samples were taken to determine other potential sources of background contamination.

Carbon tetrachloride and formaldehyde were detected in the headspace of the wells GS1 – GS4, along with benzene and toluene interpreted to be from background traffic related sources. Rubber solvent tubes were noticed on the ground in the vicinity of these wells. However, in the waste deposit soils, the only volatile organic compounds identified were cis-1,2-dichloroethene and vinyl chloride. Neither of these compounds were detected in the sorbent tubes/thermal desorption/capillary gas chromatography analysis conducted for GS01 – GS04, which is a further line of evidence to indicate that they are not migrating from the landfill towards the houses.

Report 5 also identified a number of volatile compounds in air within house number 47. This house is the furthest house from the waste deposit and provides an indication of background conditions - trace concentrations of volatile organic compounds are present in all the new houses.

Note that Environment Agency report P1-491 'Quantification of trace components in landfill gas'[1] noted that 'There are now sufficient data to demonstrate that mercury is not present in significant amounts and does not warrant inclusion on the main

[1] Quantification of trace components in landfill gas. R&D Technical Report P1-491/TR. Environment Agency December 2004. ISBN: 1 844 32397 8

priority list.' This was in relation to mercury within modern landfill gas. Gas from an older waste deposit such as found at this site would not be expected to be a significant source of volatile mercury compounds.

Recent Residential Monitoring

As of January 2019, the indoor gas monitoring indicates that:

- All radon sumps were found to contain 0-0.1ppm methane with (i.e. 0.1-0.2ppm) carbon dioxide. So close to the detection limits, these detections are likely to be artefacts of the instrument due to moisture and temperature. Taken in combination with Volatile Organic Compounds (VOCs) not being detected (all readings at 0ppm), gas monitoring demonstrates an absence of landfill gas in the radon sumps beneath the houses.
- Water Mains Manholes (with Frost Protection Caps) contain no methane (0ppm), and typical background soil carbon dioxide concentrations. VOCs were detected in 19 of the 22 water mains manholes at concentrations varying from 0.5ppm to 80.4ppm during the most recent weekly round. This is interpreted to be due to the presence of the plastic insulation frost protection cap within each chamber, with this interpretation being verified by OMI[2].

Email from RPS

The following are a number of comments from RPS re. the gas monitoring report;

- *While the Mulroy report has been read and it appears to be in order, there are no details in the drawing or the report on the passive gas vents installed so RPS don't know where they are in relation to the waste and the development.*
- *Main issue still relates to methane levels and the fact that they are still being recorded at between 5% and 15% v/v, which are the lower and upper explosive limits (LEL; UEL) of the gas. Furthermore, methane in BH4 and BH17 would seem to indicate a direct pathway from the waste body.*
- *Methane was also detected in the radon sump and the water metre (Section 1.3.19 and 1.3.20) which would indicate some connectivity. However, the levels are very low at the nearest boreholes so it would appear that, in terms of risk, it is very low risk.*
- *There are high levels of CO2 across the site over the monitoring period clearly showing that LFG is migrating from the waste body. RPS would have some concerns about the new boreholes BH15-17 showing high CO2 levels and the migration eastward, as there is a Waste Water Treatment Plant on that side.*
- *Continued and regular monitoring is required and additional passive vents should be considered around the perimeter of the waste body to provide a preferential flow path for the landfill gases.*

Updated Response:

1. With regard to the location of passive gas vents, these are located north of the waste deposit in the potential pathway between the waste deposit and the houses.
2. In terms of methane concentrations, in 2018, BH4 has consistently contained methane >5%. Overall, there have been 37 exceedances of 5% methane in other

[2] Gas Analysis of Headspace Air within gas sampling bag containing frost protection cap from House 26 and 52, Barnageeragh Cove, Skerries, Co. Dublin. OMI 31st January 2019

wells since June 2018. Fifteen of these have been in BH17 on the east of the site away from the housing, four from BH1, three have been in BH6, four from BH7, one from BH8, two from BH9, two from BH10, one from BH11 and five from BH12. The exceedances do not show an increasing trend in any well and appear to represent intermittent gas generation and/or surface sealing such that the generated gas cannot escape. Because risk is associated with both concentration and flow, the flow readings provide important context. The maximum recorded flow is 0.3 L/hr, which results in a 'low' or 'very low' risk, as per CIRIA 665. As discussed previously, gas generation is required to provide a pressure gradient to drive advective flow or diffusive flow that can overcome dilution by surface diffusion. The balance gas concentrations of inert nitrogen do not suggest significant gas generation, even in BH4.

3. Carbon dioxide is ubiquitous in the subsurface as the result of microbial respiration. Elevated concentrations (maximum >10%) of carbon dioxide are associated with wells within the waste deposit, but carbon dioxide concentrations are much reduced in locations away from the waste. For example, 0.3 – 4.3% in wells GS01 – GS04 in the pathway to the houses a few metres to a few 10's of metres away. Significant gas migration is therefore not indicated, consistent with the lack of gas generation significant to push out all the balance gas. The stream on the eastern site boundary (Report C) will provide a barrier to unsaturated zone gas flow to the east (BH15-17) and the water treatment plant, assuming such gas flow is actually occurring.
4. While continued monitoring would be good practice to ensure annual seasonal variation is understood in all wells, the lack of evidence for gas generation and gas migration suggests additional passive vents near the housing are not warranted. In order to avoid putting in a biocover/venting zone in the proximity of BH17 near the water treatment plant it is proposed that 1 - 2 passive gas venting wells are installed in this area to deal with the localised hotspot of gas generating waste in this area.

Potential Linkage C Contaminated groundwater flow north, northeast, and south from the waste deposit

Report C uses the ConSim model to determine risks to groundwater and surface waters from the waste deposit. The conceptual model involves groundwater that intercepts the base of the waste flowing to the small stream that surrounds the site area to the south (south of the railway), east (along the eastern site boundary) and north (along the northern site boundary). There is interpreted to be some preferential flow to the east/north-east through a weathered bedrock layer beneath BH11 and BH12. Factors that suggest the modelling output is reasonable are:

- Aquifer properties have not been assumed, but rather obtained from field pumping tests. The assessment of pumping test data in the appendix is robust.
- The groundwater elevations have been assessed on three separate occasions to gain a robust understanding of the groundwater flow regime and seasonal variation.
- The waste deposit has been differentiated into two waste types, with chemical of concern identified for potential surface water receptors (groundwater is not abstracted for potable use in the area and will not be abstracted and used on-site - P.Mulroy, pers. Comm. 13th July, 2018).

- Where Total Petroleum Hydrocarbon fractions were identified, they have been assigned to worst-case indicator compounds for the purposes of risk assessment e.g., Naphthalene was modelled as an indicator of the mobile end of the EC>C10 to C12 range.
- The input parameters used in the modelling have been referenced, justified, and are reasonable.
- The receptors chosen are groundwater immediately downgradient of the waste deposit and surface water 5m from the waste deposit at the eastern boundary drain. These are conservative assumptions.
- The modelled groundwater flow has been checked against a mass balance calculation, with the modelled value being higher than the recharge value indicating the model results are conservative.
- A sensitivity analysis was done, with best case and worse case assumptions modelled for the key determinand (ammonia).
- The model representativeness has also been assessed by comparing predicted and measured ammonia and chloride concentrations at BH11. While not perfect, there appears to be a reasonable correlation.

Additional modelling has been done to establish whether or not a landfill cap is the best remediation option. This has shown that if an engineered landfill cap is installed over the landfill, contaminant concentrations in groundwater at downgradient receptors are predicted to be mitigated such that the contaminant concentrations do not result in breaches of the Groundwater or Surface Water Regulations. This includes a biowindow in the cover to allow oxygen to diffuse to material next to BH4 and allow any methane to be oxidised as it migrates to atmosphere.

Once a robust dataset of groundwater and surface water concentrations indicating the interaction between the two is obtained, if the surface water impact is limited, and the capping of the waste has reduced recharge and contaminated groundwater flow, then there should be limited reasons to continue monitoring.

Waste Capping Design

The waste capping design has been reviewed. To prevent potential lateral migration after the capping has taken place, a recommendation (that has subsequently been adopted) was made to include a biowindow to be placed in the waste cap next to BH4. A biowindow is a permeable topsoil matrix that allows methane to be oxidised by natural methanotrophs within the soil as it vents to atmosphere. Oxidation can occur because the open structure topsoil matrix is permeable enough to allow air (oxygen) to diffuse into the subsurface. Oxygen diffusing into the subsurface will enhance degradation of any residual waste. Because the methane is oxidised to carbon dioxide as it travels to surface, there is no risk of methane build up in the subsurface. This prevents the possibility of lateral gas migration away from BH4, where gas generation occurs most regularly. Planting the biowindow with trees will maintain the open structure of the topsoil and further reduce infiltration of rainwater.

Topsoil Placement

Topsoil stockpiled as a result of ground clearance works as part of the development to the south of the new football pitch has been used as a landscape medium around the site. This topsoil was used for landscaping on the northern end of the landfill (i.e. where Type 1 waste exists) and to the north of the landfill where the ground was undisturbed in the past (i.e. outside the sand and gravel pit and historic landfill). Composite samples of this topsoil, originally used for agricultural purposes, has been screened against generic assessment criteria for Public Open Space (residential) end-use. This is a suitable sampling and screening method for such a material. The assessment indicates that the topsoil is suitable for its intended Public Open Space (residential) end-use, with soil concentrations being well below the generic assessment criteria used for screening.

Conclusions

1. The low and very low risks assigned to the potential landfill gas linkage in Report A and after subsequent monitoring rounds are correct and robust. There are now sufficient data to assess the effects of seasonal variation on the gas regime. A Check list for assessing the adequacy of a site investigation from BS 8485:2015 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' is included as Appendix 1.
2. The interpretation that the waste deposit is not causing vapour migration into the houses is supported by a number of lines of evidence and is therefore robust. Modelling of soil contaminant fate and transport, the lack of volatile compound detections in groundwater, and indoor air monitoring in the houses themselves all suggest that compounds in the waste deposit are not migrating to the houses.
3. The volatile compounds detected from the water mains are from the plastic insulation frost protection covers and are not believed related to the historic waste. A report from OMI is pending.
4. Under current conditions contaminant migration via the groundwater pathway may result in elevated above background concentrations of ammonia, chloride, arsenic, c-1,2-Dichloroethene and naphthalene at downgradient receptors at varying times over the 1,000 year model period. Groundwater is not used for potable supply in the area (P.Mulroy, pers. Comm. 13th July, 2018). If an engineered landfill cap is installed over the landfill, contaminant concentrations in groundwater at downgradient receptors are predicted to be mitigated.
5. If the cap contains a biowindow adjacent to BH4, any gas generated at this location will not be able to build up in the subsurface and will not be able to migrate laterally. Any gas generated will be converted to carbon dioxide as it migrates to the surface.
6. Groundwater should be monitored and assessed after the waste deposit has been capped and infiltration reduced. Once a robust dataset is available, and if no significant impact is occurring, then further monitoring should not be required. If significant impact is occurring, then additional mitigation measures and monitoring will be required.
7. The topsoil placed to landscape the area to the north of the historic landfill is suitable for a Public Open Space (residential) end-use.

CLOSURE

We trust the above proposal meets your requirements. We would be happy to discuss the details with you and incorporate any comments. If you have any questions, please contact the undersigned.

ARGENTUM FOX

Tom Parker, M.A., M.Sc., Eur.Geol., FGS. SiLC (SQP), ASoBRA (all four disciplines).
Director

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Biography

Tom has 25 years of experience resolving brownfield and landfill operational and legacy issues. Tom has written papers on the migration of vapour into residential properties, the sustainability of landfills, and the profile of trace components of landfill gas over time. He has managed many landfill R&D projects including the prioritisation of trace components in landfill gas from a toxicity and odour perspective, from both biodegradable and hazardous waste. He has also developed gas scrubbing technology for landfill gas and biofilters for methane oxidation. He has written Industry Codes of Practice, for example, on 'Perimeter soil gas emissions criteria and associated management'. Recent landfill projects include gas abstraction and migration concerns at operating and closed landfills. Brownfield projects include assessing vapour intrusion at residential properties, supporting a Public Enquiry into a residential development on an old landfill, and project managing a portfolio of residential remediation projects.
Tom trained as a hydrogeologist, is a Chartered and European Geologist, a Specialist in Land Condition (SQP), and an Accredited Risk Assessor (all four disciplines).

Appendix 1. Modified Table 1 Check list for assessing the adequacy of a site investigation. From BS 8485:2015, Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings

Aspect of the investigation	Questions that should be adequately answered	T. Parker view
Preliminary investigation	Has the preliminary investigation (desk study and site reconnaissance) been completed in accordance with BS 10175 and BS 8576? Are there any information gaps that need to be filled?	**Yes** **No**
Scope of the investigation	Has the investigation been sufficient in scope to: • establish the geology and hydrogeology of the site; • determine whether made ground and/or contamination is present; and • identify source(s) and the nature of the mechanism of gas generation? Has appropriate monitoring, sampling and analysis been carried out?	**Yes** **Yes** **Yes** **Yes**
Geophysical techniques	Where appropriate, have geophysical/remote sensing techniques been used to help delineate the extent of landfill or made ground and the location of the methanogenic material?	**Yes**
Monitoring installations	Were the type and depth of monitoring installations and response zones adequate to identify on-site gas sources and migration pathways, and to determine whether receptors were likely to be impacted? Are there sufficient monitoring installations to evaluate effects of off-site sources, where this is relevant?	**Yes** **Yes**
Distribution of monitoring points	Were monitoring locations distributed such that sources, migration pathways and receptors can be adequately characterized?	**Yes**
Monitoring instrumentation	Were the instruments used to monitor gas appropriate, and properly maintained, calibrated, and operated?	**Yes**
Monitoring parameters	Is enough information regarding gas composition, concentrations, atmospheric and differential borehole pressures and flows available to characterize risk, and is there sufficient data concerning the factors that affect gas migration and emission to assess the likely variability of the gas regime? Was the data accurately measured and reported?	**Yes** **Yes to reported. Measurement accuracy not assessed**
Monitoring frequency	Was the frequency of monitoring sufficient to characterize the consistency or inconsistency of the gas regime over the monitoring period (see **5.3**)?	**Yes**
Monitoring period	Was the period of monitoring long enough to monitor changes in ambient conditions that influence gas generation and migration (see **5.4**)?	**Yes**