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HENRY BOOT CONSTRUCTION LIMITED

GLASSWORKS – PHASE 2

DETAILED QUANTITATIVE RISK ASSESSMENT AND OUTLINE REMEDIATION STRATEGY

DECEMBER 2018

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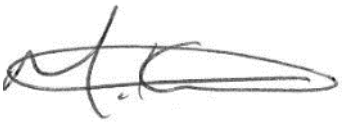
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DETAILED QUANTITATIVE RISK ASSESSMENT AND OUTLINE REMEDIATION STRATEGY

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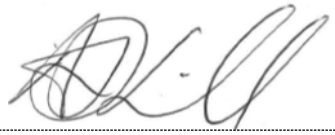
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1 INTRODUCTION

Instructions

1.1 This report is prepared in accordance with instructions from Mr M Rowbottom of Henry Boot Construction Ltd, Callywhite Lane, Dronfield, S18 2XN in an e-mail dated 13 November 2018, in accordance with the signed Terms of Appointment provided by Henry Boot Construction Ltd dated 15 November 2018. This follows a proposal dated 17 July 2018 by Wardell Armstrong. Limitations to the report are included in Appendix I.

Background

1.2 The site comprises former offices and commercial premises currently undergoing demolition. The Site is located as shown on the site location plan, Drawing No. SH12158-001 (1:50,000 plan) and more detailed site plan, Drawing No. SH12158-003 (1:500 scale).

1.3 The site is located in the centre of Barnsley, South Yorkshire, is surrounded by mixed commercial and residential areas, and is bounded by Kendray Street and Jumble Lane Crossing to the north, a railway line to the east, a private road and the Alhambra Shopping Centre to the south, and Cheapside and May Day Green to the west.

Purpose and Basis of Report

1.4 The purpose of the investigation is to provide an updated Detailed Quantitative Risk Assessment and Outline Remediation Strategy for site contamination based on results from the site investigations. An outline remediation strategy was presented in 2008 with the general scope discussed and agreed in principle with representatives from Barnsley Metropolitan Borough Council and the Environment Agency.

Proposed Site Use

1.5 It is proposed that the site will be redeveloped as mixed retail, markets and leisure uses.

2 SUMMARY OF PREVIOUS ENVIRONMENTAL INVESTIGATIONS

Wardell Armstrong Stage 2 (Pre-Demolition) Site Investigation (ref. SD08-0061 dated May 2008)

2.1 The Wardell Armstrong investigation covered a wider area of the Barnsley Markets redevelopment than the Glassworks, Phase 2 site. All the results have been included as part of this review section but areas that are outside of the Glassworks, Phase 2 site area have been highlighted.

2.2 The Stage 2 Site Investigation followed a Preliminary Stage 1 Site Investigation which was reported in November 2007. The Stage 2 investigation built on and incorporated all of the results and findings of the Stage 1 investigation. Results and conclusions of the Stage 2 investigation are summarised below.

Site Investigation Results

2.3 Observations from the intrusive work confirmed the presence of made ground comprising gravel, sand and clay with brick, mudstone, sandstone, concrete and some coal, ash and clinker over the majority of the Site. Made ground thicknesses typically varied across the Site between 2m and 3m. Thicker areas of made ground were recorded within the south-east Markets Basement, Zero Ice, Open Market and CEAG areas.

2.4 Although not identified on geological maps of the area, material considered to be of glacial origin was present in the north of the Site. The glacial deposits generally comprised firm to stiff, sandy, gravelly clay and units of sandy gravels. The gravel fraction typically consisted of mudstone, sandstone and coal.

2.5 Weathered Coal Measures were identified overlying rockhead and generally comprised stiff, gravelly clay, with the gravel fraction comprising mudstone and weak, thinly laminated mudstone.

2.6 Bedrock of the Middle Coal Measures generally consisted of weak to moderately strong, grey mudstone interbedded with siltstone and sandstone and underlain by Kent's Rock sandstone. Three coal seams interpreted as the Winter/Abdy, Top Beamshaw and Low Beamshaw coals were penetrated in strata above the Kent's Rock.

2.7 Two-hundred and seventy-three soil, twenty six groundwater and four surface water samples were collected for a suite of geochemical tests comprising volatile and semi-

volatile organic compounds; aliphatic, aromatic and polycyclic aromatic hydrocarbons; metals and other inorganic elements.

Risk to Human Health

2.8 Analytical results were analysed using CLEA methodology to assess the risk to human health in an industrial/commercial scenario. Concentrations of metals, semi-metals and non-metals recorded across the Site were not considered to present a significant possibility of significant harm to long term human health. However, the recorded concentrations of arsenic, nickel and phenols may be significant with respect to construction workers. All future groundwork on Site should be designed and planned to minimise the exposure of workers to contaminated soil.

2.9 The site investigation identified visual and olfactory evidence for hydrocarbon contamination at numerous site investigation locations. However, the maximum recorded concentrations of petroleum hydrocarbons, PAH, SVOC and VOC are below the relevant screening criteria for the majority of samples taken from across the Site. The exceptions to this are samples from the May Day Green (outside of Glassworks, Phase 2), Markets Basement and southern CEAG Hotspots (outside of Glassworks, Phase 2).

May Day Green Hotspot (Off Site)

2.10 Two samples from May Day Green recorded elevated concentrations of benzo(a)pyrene which may present a significant possibility of significant harm to long-term human health. However, all contaminated made ground within the May Day Green area is designated for disposal off-site as part of basement excavations. Therefore, the elevated benzo(a)pyrene concentrations are not considered to pose a long-term risk to future site users.

Markets Basement Hotspot

2.11 Numerous samples in the vicinity of borehole WS105A located in the south-east Markets Basement recorded elevated petroleum hydrocarbons, PAH, SVOC and VOC. It is considered unlikely that this contamination poses a significant risk to long term human health via dermal contact and/or ingestion of soil pathways due to the depth of contamination being generally greater than 3m bgl and concrete hard standing overlying the made ground. However, it is considered plausible that the more volatile petroleum hydrocarbons, SVOC and VOC contaminants may pose a significant risk to

human health via the inhalation of vapours. Further modelling was recommended to quantify the risk posed by volatile contaminants to human health.

2.12 Based on the location and type of the contaminated strata it is considered likely that the source may relate to former use of the area as a gas works.

Southern CEAG Hotspot (Off Site)

2.13 Made ground identified from the southern CEAG area recorded elevated concentrations of benzo(a)pyrene which may present a significant possibility of significant harm to long-term human health. Further modelling was recommended to assess the potential risk posed by benzo(a)pyrene to human health.

Risk to Groundwater

2.14 The Site is situated above a minor aquifer. The closest sensitive groundwater abstraction is 900m west of the Site (up gradient) and the Sough Dyke flows from east to west beneath the Site. The nearest graded surface watercourse is the River Dearne, which is approximately 900m north-east of the Site.

2.15 The concentrations of most chemicals of concern recorded within groundwater beneath the majority of the Site are below adopted screening criteria. The exceptions to this are samples from the Markets Basement and Southern CEAG Hotspots.

Markets Basement Hotspot

2.16 Groundwater monitoring in the vicinity of the Markets Basement Hotspot indicates distinct shallow and deeper groundwater bodies within made ground and Coal Measures strata. Significant contamination is only identified in the shallow groundwater suggesting that the shallow and deeper groundwater bodies are not hydraulically connected.

2.17 Elevated concentrations of arsenic, cyanide, selenium, sulphate, zinc, petroleum hydrocarbons, PAH, SVOC and VOC are recorded in shallow soil and groundwater within the Markets Basement Hotspot. These elevated concentrations are generally not considered to pose a significant risk to long term human as the nearest sensitive groundwater abstraction is almost 1km up gradient. However, due to the close proximity of the Sough Dyke the elevated concentrations may pose a risk to environmental receptors. Further modelling was recommended to quantify the potential risk to environmental receptors.

2.18 The more volatile petroleum hydrocarbons, SVOC and VOC may pose a risk to human health via the inhalation pathway. Further modelling was recommended to quantify this risk.

Southern CEAG Hotspot (Off Site)

2.19 Groundwater levels in boreholes east of the railway suggest that groundwater within made ground and Coal Measures are in hydraulic continuity and are likely to represent a single aquifer.

2.20 Elevated concentrations of selenium, TPH and PAH are recorded within soil and groundwater beneath the Southern CEAG Hotspot. Due to the close proximity of the Sough Dyke the elevated concentrations may pose a risk to environmental receptors. Further modelling was recommended to quantify the potential risk to environmental receptors.

Risk to Surface Water (Sough Dyke)

2.21 Two rounds of sampling and geochemical testing has been used to complete a preliminary assessment of water quality in the Sough Dyke. Samples were taken from upstream and downstream of the site. The maximum recorded concentrations for metals and TPH were all below Environmental Quality Standards.

2.22 Slightly elevated concentrations of PAH, SVOC and dichloromethane indicate minor impact from these compounds. However, the concentrations are considered to be indicative of background quality and not contamination identified on Site.

2.23 In addition, several water quality indicators suggest a classification of Sough Dyke as Grade E or Poor (GQA, Environment Agency).

Risk to Ecology

2.24 Arsenic, chromium and nickel were recorded at concentrations which may pose a risk to sensitive plant growth.

2.25 It is considered that the recorded metal concentrations are unlikely to pose a significant risk to standard tree and hedge planting. Risk to plant growth would be further reduced by the use of tree pits with imported soil.

2.26 There is a history of recorded knotweed presence alongside the railway, but off Site. Treatment of the knotweed should be investigated as part of the construction programme.

Risk to Buildings and Property

2.27 Results for sulphate (2:1 extract) concentration indicate that a design sulphate class of DS-4 and Aggressive Chemical for Concrete (ACEC) class of AC-3 may be appropriate for the Site.

2.28 Due to the presence of the potentially corrosive and/or organic contaminants it is recommended that wrapped iron or polythene/aluminium/polythene (PE/Al/PE) pipe material be used should water supply pipe work be installed as part of the redevelopment works.

Risk from Ground Gas

2.29 The presence and concentrations of ground gases were monitored on ten occasions, predominantly at atmospheric pressures of less than 1000mb over an eight month period.

2.30 Methane concentrations ranging from 0.3% at BH104 to 7.3% at BH202 were recorded in five boreholes across the Site. It is considered that elevated methane concentrations are a result of a combination of natural methane production from underlying coal seams, anaerobic decomposition of organic matter and vapours from impacted hydrocarbon soils and groundwater.

2.31 Slightly elevated carbon dioxide concentrations ranging from 0.1% to 7.1% were recorded across the majority of the Site during the monitoring period. The maximum recorded carbon dioxide concentrations were generally recorded at borehole BH108 which as previously indicated intersected a shallow coal seam. This suggests that the coal seam may be the likely source of carbon dioxide in this case.

2.32 Flow rates recorded during the ten monitoring visits were predominantly very low with a maximum flow rate of 1l/hr.

2.33 Boreholes BH104, BH207(shallow) and BH207(deep) are located within the Markets Basement hotspot where soils and groundwater are impacted by hydrocarbon contamination. It is considered that the elevated methane readings taken from these boreholes are likely to comprise vapours from short chain hydrocarbons. As impacted material within this area is to undergo remediation, the gas monitoring results from this area have been discounted from the data set for the purposes of the risk assessment.

2.34 It is considered appropriate that the Site is divided into two zones based on the conceptual site model. The model identifies different site uses and variance in ground

gas results between the eastern and western sides of the railway. East of the railway the Site is to be developed as multi-storey car parking with no basement. Gas monitoring results include only one slightly elevated methane concentration and relatively low carbon dioxide concentrations. West of the railway the Site is to be developed for commercial land use with basement areas and above ground level residential apartments. Recorded results include five elevated methane concentrations in two boreholes (excluding previously discounted results) and elevated carbon dioxide concentrations.

East of Railway (Off Site)

2.35 A worst case GSV of 0.053l/hr has been calculated for the Site east of the railway. The conceptual site model and gas monitoring data indicates classification of the site east of the railway as Characteristic Situation 1 low sensitivity (commercial) and moderate gas hazard (green or very low risk) based on a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

2.36 It is considered that a Characteristic Situation 1 is appropriate to the Site east of the railway based on a proposed low sensitivity end use and only one recorded elevated methane concentration.

West of Railway

2.37 A worst case GSV of 0.06l/hr has been calculated for the Site west of the railway. The conceptual site model and gas monitoring data indicates classification of the Site west of the railway as Characteristic Situation 1 low sensitivity (commercial) and moderate gas hazard (green or very low risk) based on a GSV of less than 0.07l/hr. However, as methane has been recorded above 1% consideration should be given as to whether the Site should be reclassified as Characteristic Situation 2 (low risk).

2.38 It is considered that a Characteristic Situation 2 is appropriate to the Site west of the railway due to consistently elevated carbon dioxide concentrations and elevated methane concentrations and the proposed form of development. The elevated carbon dioxide and methane may potentially originate from underlying coal seams.

Recommendations

2.39 The report made the following recommendations:

- Further assessment in the form of a detailed quantitative risk assessment to establish the risk posed by identified contamination within the Markets

Basement and Southern CEAG Hotspots to human health and environmental receptors. This should also include generation of remedial targets if required.

- Gas monitoring has identified slightly elevated concentrations of methane and carbon dioxide beneath the Site. Gas protection measures should be adopted on the Site located west of the railway.
- Basic protection against radon, for residential dwellings or new structures of similar form of construction on the Site.
- Investigation of the apparent treatment history of Japanese knotweed alongside the railway.
- Consideration to the soft landscape planting where proposed in areas of soils with elevated metal concentrations.
- Wrapped iron or polythene/aluminium/polythene (PE/Al/PE) pipe material to be used for water supply pipework to be installed as part of the redevelopment works.
- Consideration to the use of PPE to minimise exposure of workers when undertaking demolition and construction work.
- Sulphate results indicate that a design sulphate class of DS-4 and Aggressive Chemical for Concrete (ACEC) class of AC-3 may be appropriate for the Site.

Mott MacDonald Phase II Contamination Assessment Report, March 2018

2.40 Mott MacDonald carried out a site investigation in November-December 2017. In total 4 No. cable percussion boreholes, 19 No. window sample boreholes and 2 No. trial pits were advanced as part of this investigation.

2.41 The investigation identified the geology at the site to comprise:

- Made Ground (0.4 – 4.9m thick);
- Glacial Till (0 – 6.25m thick); and
- Pennine Middle Coal Measures (proven to 21.15m thick).

2.42 Groundwater was encountered during drilling at four locations at depths of 1.8 – 2.2m in the made ground (perched water) and 4.2 – 4.7m bgl in the natural deposits. The groundwater monitoring carried out as part of the investigation confirmed that there is not a continuous water body in either the made ground or the Glacial Till.

2.43 A total of thirty one soil samples were taken for laboratory analysis. When compared to commercial GACs there were no exceedances with the exception of PAHs in four

locations localised areas. Soil analysis identified presence of asbestos fibres in seven samples; six of which were taken from made ground and one from the underlying Glacial Till. One of the samples was submitted for detailed quantification and an asbestos fibre concentration of <0.001% was reported.

2.44 Soil leachate analysis assessed inorganic contaminants and identified that concentrations in the made ground at the site have the potential to be mobile if leaching occurs.

2.45 A waste assessment was also carried out which identified that 14 out of 31 samples analysed would be classified as hazardous if removed from site.

2.46 Groundwater analysis indicated that free product may be present in perched water due to concentrations of organic contaminants exceeding their theoretical solubility limits. One TPH fraction at WS11D was identified as exceeding the SOBRA screening criteria for vapour risk and therefore may pose an inhalation risk to site end users in commercial buildings. Other than the potential vapour risk, the risk to groundwater is considered to be low due to presence of hardstanding at surface.

2.47 The ground gas risk was considered low (CS2) based on recent and historical monitoring data. Ground gas protection measures will be required in new buildings for a CS2 site, as set out in CIRIA C665.

2.48 The Mott MacDonald report recommended the following:

- *Ensure a Construction Environmental Management Plan is produced and followed, this should include methods for storing materials and fuel on site during construction and methods for controlling dust.*
- *A methodology to deal with unexpected contamination should be produced and followed during site works, this should require contractors to stop work and report any unexpected contamination to allow the risk assessment to be updated and remedial measures identified (if required).*
- *Construction workers should use appropriate PPE at all times during site works.*
- *Ground gas protection measures suitable for a CS2 site should be included in the design of new buildings.*
- *A Foundation Works Risk Assessment should be undertaken to confirm that the piling techniques will not pose unacceptable risks to environmental or human health receptors.*

- *It is recommended that remedial measures are employed to address the moderate risk related to vapour intrusion into buildings in the area of WS11. This may include either use of a vapour membrane in the building located in this area of the site, or additional ground investigation to inform disposal or treatment of the source.*
- *It is recommended that remedial measures are employed to confirm the cover system required in areas of minor soft landscaping (tree pits and planting beds) this should be covered in a remediation strategy for the site.*
- *Buried concrete to be designed in accordance with BRE Special Digest No.1. New water supply pipes to be designed according to UKWIR specifications in consideration of the ground conditions encountered.*
- *Any dewatering (likely to be needed for excavations below 4.2m, perched water may be encountered shallower) should consider options for groundwater disposal as it is unlikely to be suitable to dispose of to ground or surface waters. Discussions may be required with the Environment Agency and/ or the water company regarding this.*
- *It is not recommended that groundwater is allowed to drain through the basement of the new buildings unless a detailed quantitative risk assessment is undertaken and confirms acceptable risks associated with this. There are potentially volatile contaminants in the groundwater which may pose a risk to site end users. Any groundwater drained from site will not be appropriate for disposal to river or to ground and it is recommended that discussions are held with the water company to identify if this could be disposed of via foul drainage.*
- *An asbestos specialist should be contacted to advise on asbestos risk and management.*
- *Disposal of material off site should be discussed with a waste carrier as a large percentage of material is likely to be hazardous due to contaminant levels measured. If reuse of material is proposed, the suitability of the material for the proposed purpose should be assessed and managed under a Materials Management Plan or Environmental Permit.*

3 REVISED CONCEPTUAL SITE MODEL

3.1 In line with current Environment Agency guidance, plausible source, pathway and receptor linkages have been identified for the site. The plausible linkages are discussed below and indicated in the conceptual model (Table I).

Source

3.2 The following assessment is based on a diverse suite of geochemical analyses of soil samples and groundwater samples collected from across the site during the previous site investigations.

3.3 WS105A and WS119 were not purged prior to groundwater sampling and therefore it is not considered appropriate to use the concentrations recorded in the DQRA as the groundwater samples obtained are not considered representative. Alternative representative groundwater samples were obtained from boreholes drilled as part of the Stage 2 investigation within the vicinity of boreholes WS105A and WS119 (BH207 and BH213A).

Metals

Groundwater

3.4 Deep and shallow groundwater is contaminated with zinc and shallow groundwater is contaminated with selenium in the vicinity of the former market basement.

TPH

Soil

3.5 Soil beneath the former market basement is contaminated with petroleum hydrocarbons.

Groundwater

3.6 Shallow boreholes screened within the made ground in the former market basement are contaminated with petroleum hydrocarbons. Deep groundwater is not significantly contaminated with petroleum hydrocarbons.

PAH/SVOC

Soil

3.7 Soil within the former market basement and to the south of the site is contaminated with benzo(a)pyrene, dibenzo(a,h)anthracene, carbazole, naphthalene and phenol.

Groundwater

3.8 Shallow groundwater within the former market basement is contaminated with PAH and SVOC. One species of phenol has been detected at a low concentration within deep groundwater beneath the former market basement. Based on the detailed phenol analysis, this substance within deep groundwater is not considered to present a significant risk to the environment.

VOC

Soil

3.9 Soil within the former market basement is contaminated with benzene, toluene and styrene.

Groundwater

3.10 Shallow groundwater beneath the former market basement is contaminated with VOC. Deep groundwater beneath the former market basement is not significantly contaminated with VOC.

Other Analytes

Soil

3.11 Soil within the former market basement is contaminated with cyanide.

Groundwater

3.12 Shallow groundwater beneath the former market basement is contaminated with cyanide and sulphate. Deep groundwater beneath the Markets Basement Hotspot is not significantly contaminated with cyanide or sulphate.

Pathways

Human Health

3.13 In terms of human health the main pathways are considered to be dermal contact, ingestion and inhalation.

3.14 Construction workers are likely to be at risk from all three potential pathways whilst working on the site. Future occupiers are only likely to be affected by inhalation as the majority of the site will be covered in buildings and hardstanding with minor landscaped areas. Therefore, future occupiers are unlikely to come into contact with soils via ingestion or dermal contact.

Groundwater

3.15 The main pathway by which contaminants are likely to reach groundwater is through infiltration of rainwater causing vertical movement through the ground. The proposed development will be predominantly covered by hardstanding, thus significantly reducing the risk to groundwater.

Surface Water

3.16 The main pathway by which contaminants are likely to reach the Sough Dyke is through migration of shallow groundwater. This pathway is considered viable and is considered throughout the following assessment.

Receptors

3.17 A number of sensitive receptors have been identified in close proximity to the site. These receptors are:

- Shallow and deep groundwater;
- Surface water in the nearby Sough Dyke; and
- Future human receptors (site occupiers and construction workers).

Summary

3.18 Based on the land use history and identified sources of contamination, a conceptual site model has been developed. This is shown in Table I and details the potential sources, pathways and receptors and the inter-relationship of these factors.

3.19 The most critical source-pathway-receptor linkage identified is the migration of contaminants of concern within soil and shallow groundwater to the Sough Dyke.

3.20 It is considered that the risks on site are as follows:

TABLE I

Source	Pathway	Receptor	Risk
TPH BTEX SVOCs PAHs Phenols Zinc	Infiltration	Groundwater	Moderate
	Lateral migration	Sough Dyke	Moderate
	Ingestion of soil	Construction workers	Low to Moderate
	Dermal contact with soil	Construction workers	Low to Moderate
	Migration and	Construction workers	Low to Moderate

TABLE I			
Source	**Pathway**	**Receptor**	**Risk**
Selenium Cyanide Sulphate	Collection of vapours	Future residents	Low to Moderate

3.21 Any remediation undertaken at the site should be designed to protect human health and the environment by reducing source concentrations within the soil and shallow made ground aquifer beneath the site to acceptable concentrations.

4 HUMAN HEALTH DETAILED QUANTITATIVE RISK ASSESSMENT

Introduction

4.1 The Contaminants of Concern (COC) identified in the Generic Quantitative Risk Assessment are TPH, benzene, benzo(a)pyrene, benz(a)anthracene, benzo(b)flouranthene, chrysene, dibenzo(a,h)anthracene, naphthalene, carbazole, phenols and asbestos with regards to the risk to human health.

4.2 The Environment Agency Contaminated Land Exposure Assessment (CLEA) model has been used to assess the risk to human health and derive site specific assessment criteria (SSAC) which can be adopted as remedial targets. This model was used to derive SSAC for soil for benzene, naphthalene, phenol and benzo(a)pyrene. Generic human health screening values have been adopted for the other COC e.g. LQM S4UL's, C4SL's.

TPH

4.3 Analytical results for petroleum hydrocarbons have been compared with Generic Assessment Criteria (GAC) for commercial/industrial land use.

4.4 The maximum recorded concentrations of aromatic and aliphatic petroleum hydrocarbons (C5-35) have been compared to their relevant generic assessment criteria, shown below in Table II. The screening criteria are based on a soil organic matter content of 2.5%.

4.5 There are no exceedances for short chain-length aliphatic (C5-C35) or aromatic (C6-16) fractions. Although there are exceedances for aromatic fraction C21-35 at a depth of 3.8m below the site, it is considered unlikely that this material presents a significant risk to long term human health.

PAH/SVOC

4.6 Analytical results for PAH/SVOC have been compared with GAC for commercial/industrial land use.

4.7 The maximum recorded concentrations of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, naphthalene and carbazole have been compared to their relevant generic assessment criteria, shown below in Table II. The screening criteria are based on a soil organic matter content of 2.5%. Although there are exceedances for all these contaminants, it is considered unlikely that SVOC contamination at a depth of 3.8m bgl poses a significant risk to long term human

health via dermal contact and/or ingestion of soil pathways. Therefore, the maximum concentration of PAH contaminants located at depths of less than 1m bgl have been used in the CLEA UK model to derive Site Specific Assessment Criteria for PAHs. It is considered plausible that naphthalene, the most volatile SVOC may pose a significant risk to human health via the inhalation of vapours. Therefore, the CLEA UK model has been used to derive Site Specific Assessment Criteria for naphthalene.

VOC

4.8 Analytical results for VOC have been compared with GAC for commercial/industrial land use.

4.9 The maximum recorded concentration of benzene is above the generic assessment criteria, as shown below in Table II. The screening criteria are based on a conservative soil organic matter content of 2.5%. Concentrations of benzene may pose a significant risk to human health via the inhalation of vapours.

Future Occupiers

Introduction

4.10 The risk assessment has been undertaken in accordance with relevant UK guidance as presented in SR2 to SR4; the Contaminated Land Exposure Assessment (CLEA) regime published by DEFRA and the EA.

4.11 CLEA V1.071 has been derived by the Environment Agency and is able to derive generic assessment criteria (GAC), site specific assessment criteria (SSAC) and calculate average daily exposure/health criteria that are compatible with current UK legislation with regard contaminated land.

4.12 The maximum concentrations summarised below in Table II were obtained from samples taken below current site levels and are in excess of generic assessment criteria. Where there is a C4SL value available for the contaminants, these have been adopted as more pragmatic assessment criteria in Table II.

Table II – Human Health Generic Assessment Criteria			
Contaminant	**Maximum Recorded Concentration (mg/kg)**	**Maximum Recorded Concentration <1mbgl (mg/kg)**	**Commercial/ Industrial (mg/kg)**
Aromatic petroleum hydrocarbons C21-C35	**29,000**	-	28,000[1]
Benzo(a)pyrene	**1,000**	**625**	77[2]
Benz(a)anthracene	**1,500**	**977**	95[1]
Benzo(b)fluoranthene	**950**	**745**	100[1]
Chrysene	**1,300**	**678**	140[1]
Dibenzo(a,h)anthracene	**140**	**90.8**	3.5[1]
Naphthalene	**9,100**	**2,520**	480[3]
Benzene	**200**	0.155	98[2]
Carbazole	**590**	1.6	86.2[4]
Phenol	**2,500**	4.63	1,500[1]
Asbestos Fibres in Soil	**Detect/<0.001%**	**Detect/<0.001%**	Non-detect/<0.001%

Notes:

[1] LQM/CIEH generic assessment criteria (S4UL's)

[2] DEFRA Category 4 Screening Values (C4SL's)

[3] LQM/CIEH generic assessment criteria

[4] US Environmental Protection Agency, Preliminary Remediation Goals

CLEA Model: Soil to Future Occupiers Exposure Pathways

4.13 The generic exposure pathways considered in the CLEA model are:

- Ingestion of soil and soil derived dust;
- Consumption of homegrown produce;
- Ingestion of soil attached to homegrown produce;
- Skin contact with soil and soil derived dust indoors;
- Skin contact with soil and soil derived dust outdoors;
- Inhalation of soil derived dust indoors;
- Inhalation of soil derived dust outdoors;
- Inhalation of vapours outdoors; and
- Inhalation of vapours indoors.

4.14 It is proposed that the site area will be covered by hardstanding or vegetative cover which will prevent skin contact, consumption and ingestion pathways. Therefore, these pathways have not been included within the modelling.

Critical Receptor

4.15 Future occupiers of the site are considered to be the primary receptors with the potential for long term exposure and chronic health risks. A female adult (aged 16-59) is considered the most susceptible receptor of this scenario.

Input Parameters

4.16 The site specific input parameters for the CLEA model are presented in Table III below. CLEA Worksheets are attached at Appendix II.

Table III

Selected Input Parameters

Site Parameter	Selected Parameter	Parameter Source
Soil Type	Clay	SR3*.
SOM Content	3%	Site specific Geomean.
Fraction of site with hard or vegetative cover	100%	Estimate based on developed site largely covered by hardstanding, buildings and trees/grass.
Building Type	Office (post 1970)	SR3* value.
Depth to top of source (no building)	380cm	Based on shallowest depth of elevated contamination.

**Science Report SC050021/SR3: Updated technical background to the CLEA model.*

Site Specific Assessment Criteria

4.17 Site specific assessment criteria have been derived for benzene, naphthalene, phenol and benzo(a)pyrene, as a surrogate compound for all PAHs, using the parameters indicated in Table III to establish whether these substances present a risk to long term human health via the inhalation pathway at depths of greater than 3.8m bgl for benzene, naphthalene and phenol and at depths of less than 1m bgl for benzo(a)pyrene. A conservative soil organic matter (SOM) content of 3% has been utilised. This value represents the site wide, geometric mean for made ground excluding contaminated samples.

4.18 It is proposed that the site area will be covered by hardstanding or vegetative cover which will prevent dermal contact and ingestion pathways. Therefore, these pathways have not been included within the modelling.

4.19 The site specific assessment criteria (inhalation pathway) for benzene, naphthalene and phenol have been calculated at 4,856mg/kg, 26,363mg/kg and 931,046mg/kg respectively. The maximum concentrations of benzene, naphthalene and phenol are well below the site specific assessment criteria (Table IV). Therefore, it is considered that volatile contaminants at 3.8m bgl beneath the site do not pose a significant risk to long term human health via the inhalation pathway. If these contaminants are brought to within 1m bgl, they may pose a significant risk to long term human health.

Table IV – Human Health Site Specific Assessment Criteria (mg/kg)

Contaminant	Maximum Recorded Concentration	SSAC		
		All Pathways	Inhalation of Vapours only	Inhalation of Soil Derived Dusts only
Benzene	200	**4,856**	4,895	608,000
Naphthalene	7,100	**26,270**	28,363	356,000
Phenol	2,500	**931,046**	1,205,000	4,093,000

4.20 The site specific assessment criteria (inhalation pathway) for benzo(a)pyrene has been calculated at 275mg/kg. The maximum concentration of benzo(a)pyrene is above the site specific assessment criteria (Table V) indicating that benzo(a)pyrene, and therefore PAHs in general, may pose a significant risk to human health in shallow soils at the site.

4.21 The inhalation of soil derived dusts pathway appears to be the most significant pathway for the contaminants of concern due to their relatively high inhalation toxicity. However, following the development of the site with hardstanding and buildings, the only significant source of soil exposure would be in any landscaped areas. Therefore, providing contaminated soils are placed at depths of greater than 1m below finished levels or beneath buildings or hardstanding, it will be possible to mitigate against the potential significant risk to long term human health from PAHs in soil on site.

Table V – Human Health Site Specific Assessment Criteria (mg/kg)				
Contaminant	Maximum Recorded Concentration	SSAC		
		All Pathways	Inhalation of Vapours only	Inhalation of Soil Derived Dusts only
Benzo(a)pyrene	625	**275**	6,639	286

Construction Workers

4.22 Redevelopment of the site is expected to expose soil containing elevated concentrations of PAHs, VOCs and TPH. These substances are considered to present a significant risk to construction workers without mitigation. Suitable mitigation measures include:

- Use of personal protective equipment such as gloves and masks during excavations;
- Dust suppression employed in the form of a water mist during excavations;
- Dust monitoring of generation and levels employed throughout the works; include visual checks and use of a portable, hand held dust meter; and
- Any stockpiles of excavated material will need to be kept damp and placed in a designated area lined and securely covered with polythene sheets or similar.

5 CONTROLLED WATERS DETAILED QUANTITATIVE RISK ASSESSMENT

Introduction

5.1 The Contaminants of Concern (COC) identified in the Generic Quantitative Risk Assessment are TPH, BTEX, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, naphthalene, phenol, selenium and zinc with regards to the risk to controlled waters.

5.2 The Environment Agency Remedial Targets Worksheet 3.1 was utilised to assess the risk to controlled waters and derive remedial targets. Input parameters have been sourced from site investigation data, where available, and from default values in the CONSIM help file, EA SR7 Report, RIVM Report 711701023 and Total Petroleum Hydrocarbon Criteria Working Group series. This spreadsheet was used to derive remedial targets for groundwater for TPH, BTEX, benzo(a)pyrene, naphthalene, phenol and zinc.

Soil to Groundwater Risk Assessment Methodology

5.3 The risk assessment model used to assess the impact of the contamination upon the identified receptors is the Environment Agency's Remedial Targets Methodology. The methodology is based on a risk assessment approach incorporating a source-pathway-receptor analysis that leads to the derivation of site specific remediation criteria based on an assessment of the potential impact at the identified receptor.

5.4 Remedial targets are derived at each level within the model, following progressive data collection and analysis. Generally, the remedial targets become less onerous at each Level as additional complexity can be included in the model to take into account processes such as natural attenuation. These processes can affect contaminant concentrations between source and receptor.

5.5 The assessment in relation to contaminated soil commences at Level 1 and considers the contaminants' leaching potential from the soil zone (Level 1), the dilution effect on leachate entering the underlying groundwater (Level 2) and advection and attenuation within the saturated zone (Level 3). Thus, the assessment levels for contaminated soils are:

- **Level 1 -** the contaminant concentration in the soil pore water is compared directly to the target concentration. The contaminant concentration in the soil pore water can be estimated by laboratory soil leaching tests or derived from theoretical equations via the soil contaminant concentration.

- **Level 2** - the observed contaminant concentration in the soil pore water (or leachate concentration or soil concentration as discussed above in Level 1) is compared directly to the target concentration, multiplied by the dilution factor to account for dilution within the aquifer, at an abstraction or in the receiving surface water.
- **Level 3 and 4 -** the observed soil pore water concentration (or leachate concentration or soil concentration as discussed above in Level 1) is compared directly to the target concentration multiplied by both a dilution factor (Level 2) and an attenuation factor to account for dispersion, retardation and degradation. Levels 3 and 4 are distinguished by the sophistication of the site investigation information required, modelling and prediction processes.

Groundwater Risk Assessment

5.6 A Level 3 groundwater risk assessment using the Remedial Targets Worksheet 3.1 has been undertaken to determine remedial targets for the groundwater contaminated with the COC.

5.7 The assessment in relation to contaminated groundwater commences at Level 2 as the contaminants have already moved through the soil zone, so that the only processes of significance are attenuation, dispersion and further dilution of the groundwater as it moves from the source towards the receptor. Thus, the assessment levels for contaminated groundwater are:

- **Level 2 -** the observed contaminant concentration in groundwater below the site is compared directly to the target concentration.
- **Levels 3 and 4** - the observed groundwater concentration below the site is compared directly to the target concentration and multiplied by an attenuation factor. Levels 3 and 4 are distinguished by the sophistication of the site investigation information required, modelling and prediction processes. In particular, Level 3 assessment only considers dilution within the aquifer. Dilution within the receptor (surface water or abstraction) is considered at Level 4.

Target Values for Soil and Groundwater

TPH

5.8 As there is no agreed water quality standard applicable to individual TPH fractions, the approach of using The Surface Waters (Abstraction for Drinking Water) (Classification)

Regulations 1996 for TPH of 0.5mg/l as the target concentration for each fraction has been applied except for benzene, toluene and xylene which are discussed below.

PAH

5.9 The maximum allowable EQS (freshwater) values for benzo(a)pyrene and naphthalene of 0.00027mg/l and 0.13mg/l have been selected as the respective target concentrations. As the PAH compounds have similar physiochemical properties to benzo(a)pyrene, the latter has been used as a surrogate compound for all PAHs in the assessment.

Phenols

5.10 The EQS (freshwater) of 0.0077mg/l for phenol has been selected as the target concentration.

VOCs

5.11 The maximum allowable EQS (freshwater) of 0.05mg/l for benzene, 0.074mg/l for toluene and 0.3mg/l for xylenes (total) have been selected as the target concentrations.

Carbazole

5.12 As there is no UK based water quality standard available for carbazole, the USEPA Region 9 PRG for tap water of 0.0034mg/l has been selected as the target concentration.

Zinc

5.13 The EQS (freshwater) of 0.0109mg/l for zinc has been selected as the target concentration. Selenium has similar physical properties to zinc. Therefore, zinc has been used as a surrogate compound for selenium.

Soil and Groundwater Risk Assessment Input Parameters

5.14 The quantitative risk assessment is based on assessing the risks to the most sensitive receptor and the assessment initially adopts a site wide source to target contamination hotspots. In the first instance, the nearest sensitive receptor has been identified as the Sough Dyke.

5.15 The input values for the risk assessment and justification for the various parameters are set out in Table VI and Table VII. Results of the risk assessment calculation are given in Appendix III.

5.16 Remedial Targets are presented in Tables IX and X.

5.17 The Ogata Banks solution used accounts for attenuation in three ways:

- Dispersion of contamination along the flow path;
- Partitioning of a substance in solution onto solid phase; and
- The half-life of determinands due to chemical reaction and biological degradation.

TABLE VI: INPUT PARAMETERS AND JUSTIFICATION		
Parameter	Value	Justification
Hydraulic conductivity	0.0092 m/day	Site specific value from falling head test data within made ground.
Hydraulic gradient	0.024	Based on site specific groundwater levels.
Effective porosity	0.6	Based on Consim values for clay.
Fraction of Organic Carbon Saturated Zone (Level 3) Unsaturated Zone (Level 1)	 0.02 0.02	Geometric mean of made ground samples.
Bulk Density Aquifer (Level 3) Unsaturated Zone (Level 1)	 1.6g/cm^3 1.6g/cm^3	SR3 Default for clay.
Groundwater flow	SW-NE	Most likely direction based on groundwater data.
Saturated aquifer thickness	5.1m	Estimate based on local thickness of made ground.
Mixing zone thickness	5.1m	Conservative estimate based on 100% mixing in aquifer.
Distance to compliance Point	5m	Distance to Sough Dyke.
Longitudinal dispersivity ax	0.5	10% of pathway length.
Transverse dispersivity az	0.05	10% of longitudinal dispersivity.
Vertical dispersivity ay	0.005	10% of transverse dispersivity.
Time since pollutant entered groundwater	18,250	Estimate based on site history – 50 years.
Infiltration	9.5 x 10^{-4} m/d	Based on long term averages of rainfall for the site with 100% infiltration.
Water filled soil porosity	0.3	SR3 Default for clay.
Air filled soil porosity	0.3	

TABLE VII: ANALYSIS INPUT PARAMETERS				
Contaminant	Maximum recorded concentrations		Water Quality Target Concentration (µg/l)	Source
	Soil (mg/kg)	Groundwater (µg/l)		
Aliphatic C8-C10	5.8	**1,200**	500	The Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996
Aliphatic C10-C12	7.2	**4,000**		
Aliphatic C12-C16	3,100	**<10**		
Aliphatic C16-C35	2,640	**<10**		
Aromatic C8-C10	18	**3,300**		
Aromatic C10-C12	11	**6,000**		
Aromatic C12-C16	5,200	**3,200**		
Aromatic C16-C21	16,000	**550**		
Aromatic C21-C35	29,000	**150**		
Benzene	200	**16,000**	50	EQS
Toluene	310	**4,800**	74	
Xylene	11,900	**1,670**	300	
Benzo(a)pyrene	1,000	**1.9**	0.27	
Napthalene	9,100	**10,000**	130	
Phenol	2,500	**93,500**	7.7	
Zinc	250	**170**	10.9	
Carbazole	590	**8**	3.4	USEPA PRG

5.18 A conservative degradation half-life value of 9.9×10^{99} years has been used. However, for more volatile and biodegradable organic compounds with a smaller molecular weight (benzene, toluene, xylene, naphthalene, benzo(a)pyrene and phenol) degradation has been considered in this risk assessment and the values used are listed in Table VIII. In order to ensure that a conservative approach is adopted, degradation has only been applied to the dissolved phase contaminants.

5.19 The individual Remedial Target Worksheets contain information on the source of the selected parameters. The source of the selected parameters is further justified as follows:

- The length and width of the plume has been conservatively estimated to be 40m by 30m based on the chemical analysis results from the area.
- A value of 18,250 days (50 years) has been used for time since pollutant entered groundwater based on the site's land use history.

- The effective porosity of the made ground has not been previously determined and a conservative value of 0.6 has been selected from CONSIM data for clay.
- The fraction of organic carbon (Level 3) has been taken as 0.02 based on site measured values of the alluvium.
- The plume depth within the Level 3 groundwater Remedial Targets Worksheet has been taken as occupying 80% of the saturated zone, which is considered conservative.
- The hydraulic gradient has been taken as 0.024 given the relatively shallow topography of the site area.
- The hydraulic conductivity has been taken as 0.0092m/day has been selected based on site measurements.
- Physical properties for individual chemicals (Henry's Law constant, organic carbon partition coefficient etc.) have been collected from various sources including:
    - RIVM Report 711701023, 2001;
    - Total Petroleum Hydrocarbon Working Group Series, 1998;
    - Review of the Fate and Transport of Selected Contaminants in the Soil Environment, T5-079/TR1, September 2003, Environment Agency; and
    - Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values, Science Report 7, November 2008, Environment Agency.

Table VIII - Degradation Input Parameters

Contaminant	Degradation Half Life (Days)
Benzene	720
Toluene	22
Xylenes	360
Benzo(a)pyrene	1064.2
Naphthalene	258
Phenol	7

5.20 The results of the risk assessment are presented in Section 6.

6 REMEDIATION TARGETS

Introduction

6.1 The risk assessment undertaken is considered to be appropriate for the site. Input parameters have been selected to represent likely conditions at the site. The contamination on site is due to historic usage and the source is likely to be declining, with a resulting natural decrease in concentration over time.

Discussion

6.2 In the initial assessment the Sough Dyke was taken as the nearest sensitive receptor to the site. However, monitoring of the Sough Dyke has demonstrated that it is not impacted by contamination at the site. This is likely to be due to it being protected by the culvert construction and not being in continuity with the shallow groundwater beneath the site. Therefore, as deep groundwater is also not impacted by the contamination beneath the site, the nearest sensitive receptor is the Barnsley Canal, 680m north east of the site.

6.3 Soil and groundwater remedial targets have been revised using the Barnsley Canal as the receptor and the calculated values are presented in Tables X and XII.

Soil and Groundwater Remedial Targets

6.4 A summary of the calculated soil and groundwater remedial targets is presented below in Tables IX, X, XI and XII.

TABLE IX – Soil Remedial Targets – Sough Dyke Receptor (mg/kg)					
COC	**Maximum Recorded Conc.**	**Site Specific Environmental Remedial Targets**			**Human Health Remedial Target**
		Level 1	**Level 2**	**Level 3**	
TPH Ali C8-10	5.8	275	283	No Impact	4,800
TPH Ali 10-12	7.2	2,160	2,220	No Impact	23,000
TPH Ali C12-16	3,100	48,300	48,700	No Impact	82,000
TPH Ali C16-35	2,640	5,170,000	5,320,000	No Impact	1,700,000
TPH Aro C7-8 (Toluene)	310	0.287	0.295	385	110,000
TPH Aro C8-10	18	14.4	14.8	85.3	8,100
TPH Aro C10-12	11	22.7	23.3	1,180	28,000
TPH Aro C12-16	5,200	45.1	46.4	2,230,000	37,000
TPH Aro C16-21	16,000	127	131	No Impact	28,000
TPH Aro C21-35	29,000	1,130	1,160	No Impact	28,000
Benzo(a)pyrene	1,000	0.625	0.643	No Impact	6,639*
Carbazole	590	0.048	0.0495	**0.0659**	86.2
Benzene	200	0.0712	0.0733	**0.105**	4,856*
Naphthalene	9,100	1.53	1.58	**4.36**	26,270*
Phenol	2,500	0.00543	0.00559	24,800	931,046*
Zinc	250	20.8	21.4	No Impact	730,000
Xylenes total	500	2.47	2.54	**5.18**	14,000

*SSAC derived in Section 4

Note: values shown in bold are greater than the adopted screening value.

TABLE X – Soil Remedial Targets – Barnsley Canal Receptor (mg/kg)					
COC	**Maximum Recorded Conc.**	**Site Specific Environmental Remedial Targets**			**Human Health Remedial Target**
		Level 1	**Level 2**	**Level 3**	
TPH Ali C8-10	5.8	275	283	No Impact	4,800
TPH Ali 10-12	7.2	2,160	2,220	No Impact	23,000
TPH Ali C12-16	3,100	48,300	48,700	No Impact	82,000
TPH Ali C16-35	2,640	5,170,000	5,320,000	No Impact	1,700,000
TPH Aro C7-8 (Toluene)	310	0.287	0.295	1.56×10^{57}	110,000
TPH Aro C8-10	18	14.4	14.8	85.3	8,100
TPH Aro C10-12	11	22.7	23.3	1,180	28,000

TPH Aro C12-16	5,200	45.1	46.4	No Impact	37,000
TPH Aro C16-21	16,000	127	131	No Impact	28,000
TPH Aro C21-35	29,000	1,130	1,160	No Impact	28,000
Benzo(a)pyrene	1,000	0.625	0.643	No Impact	6,639*
Carbazole	590	0.048	0.0495	No Impact	86.2
Benzene	200	0.0712	0.0733	7.61×10^{14}	4,856*
Naphthalene	9,100	1.53	1.58	No Impact	26,270*
Phenol	2,500	0.00543	0.00559	1.11×10^{97}	931,046*
Zinc	250	20.8	21.4	No Impact	730,000
Xylenes total	500	2.47	2.54	No Impact	14,000

*SSAC derived in Section 4

Note: values shown in bold are greater than the adopted screening value.

TABLE XI – Groundwater Remedial Targets – Sough Dyke Receptor (mg/l)		
COC	**Maximum Recorded Conc.**	**Level 3 Remedial Target**
TPH Ali C8-10	1.2	No Impact
TPH Ali C10-12	4	No Impact
TPH Ali C12-16	<0.01	No Impact
TPH Ali C16-35	<0.01	No Impact
TPH Aro C7-8 (Toluene)	5.5	1.57×10^{25}
TPH Aro C8-10	3.3	No Impact
TPH Aro C10-12	6	No Impact
TPH Aro C12-16	3.2	No Impact
TPH Aro C16-21	0.55	No Impact
TPH Aro C21-35	0.15	No Impact
Benzene	16	437
Benzo(a)pyrene	0.0019	No Impact
Carbazole	0.008	No Impact
Naphthalene	10	No Impact
Phenol	123	1.37×10^{46}
Zinc	0.17	No Impact
Xylenes total	1.67	No Impact

TABLE X – Groundwater Remedial Targets – Barnsley Canal Receptor (mg/l)		
COC	**Maximum Recorded Conc.**	**Level 3 Remedial Target**
TPH Ali C8-10	1.2	No Impact

TABLE X – Groundwater Remedial Targets – Barnsley Canal Receptor (mg/l)		
COC	**Maximum Recorded Conc.**	**Level 3 Remedial Target**
TPH Ali C10-12	4	No Impact
TPH Ali C12-16	<0.01	No Impact
TPH Ali C16-35	<0.01	No Impact
TPH Aro C7-8 (Toluene)	5.5	No Impact
TPH Aro C8-10	3.3	No Impact
TPH Aro C10-12	6	No Impact
TPH Aro C12-16	3.2	No Impact
TPH Aro C16-21	0.55	No Impact
TPH Aro C21-35	0.15	No Impact
Benzene	16	No Impact
Benzo(a)pyrene	0.0019	No Impact
Carbazole	0.008	No Impact
Naphthalene	10	No Impact
Phenol	123	No Impact
Zinc	0.17	No Impact
Xylenes total	1.67	No Impact

Summary

6.5 Results from the detailed quantitative risk assessment indicate that, when considering the Sough Dyke as the most sensitive receptor there is a significant risk to the environment from elevated concentrations of carbazole, benzene, naphthalene and xylene in soil. However, as previously stated, monitoring of the Sough Dyke has demonstrated that it is not being impacted by contamination beneath the site. This is likely to be due to it being protected by the culvert construction and not being in continuity with the shallow groundwater beneath the site. Therefore, as deep groundwater is also not impacted by the contamination beneath the site, it is reasonable to use the Barnsley Canal as the nearest sensitive receptor.

6.6 Results from the detailed quantitative risk assessment when considering the Barnsley Canal as the most sensitive receptor indicate there is no significant risk to the environment from soil and groundwater contamination at the site.

6.7 Based on the all of the available information, remediation is not recommended at the site to protect the environment. This approach should be agreed in advance with the Environment Agency and Local Authority Contaminated Land Officer.

7 RISK ASSESSMENT SUMMARY

Human Health

Future Occupiers

7.1 The detailed risk assessment has identified a potential significant risk to human health from PAHs in shallow made ground. However, this potential risk can be mitigated against if contaminated soils are placed at depths of greater than 1m below finished levels or beneath buildings or hardstanding.

7.2 Asbestos fibres were identified in seven samples across the site. One sample was submitted for detailed quantification and the fibre concentration recorded was <0.001%. Therefore, asbestos fibres in soil may present a significant risk to human health at the site.

Construction Workers

7.3 PAHs were detected at levels that were elevated with respect to the CLEA assessment criteria and asbestos was identified in made ground. Precautionary health and safety measures should be employed during construction and any construction arising's containing made ground generated in these areas should be tested for asbestos and suitable mitigation will be required as discussed below.

7.4 Where possible the groundworks and the implementation of mitigation measures on site should be designed and planned to minimise the exposure of workers to contaminated soil. This should be taken into account in the Health and Safety plan under the CDM regulations. Where risks cannot be removed entirely at this planning stage, mitigation measures should include the use of appropriate personal protective clothing (PPE) including gloves, eye protection and, where necessary, respiratory facemasks. Dust suppression measures should also be incorporated into the works to reduce ingestion and inhalation of contaminated dust. Decontamination facilities should be provided during the site works.

Controlled Waters

7.5 Elevated soil concentrations of naphthalene, phenol, benzene, toluene, xylenes and carbazole present a potential risk to the Sough Dyke via migration through shallow groundwater.

7.6 Two rounds of sampling and chemical testing of the Sough Dyke, upstream and downstream, suggest that hydrocarbon contamination on site is not adversely

impacting water quality in this culverted water course. The assessment demonstrates that attenuation within the shallow groundwater, limited seepage of contaminated groundwater into the Sough Dyke and dilution within the watercourse are probably significant in reducing the impact to water quality. When considering the Barnsley Canal as the nearest sensitive receptor there is considered no impact from contamination on the site.

7.7 No specific remediation is recommended for controlled water although any contaminated water encountered during excavation works will need treatment before being discharged.

Remediation

7.8 The results of the analysis of the ground investigations through the DQRA at the site have concluded that some minor remedial works will be required to minimise the risk to future occupiers of the site.

8 OUTLINE REMEDIATION STRATEGY

Introduction

8.1 Environment Agency guidance, CLR 11, provides the technical framework for applying a risk management process when dealing with land affected by contamination and includes a remediation options appraisal stage between the risk assessment and implementation of remediation stages.

8.2 Presented below is an assessment of remedial options that could potentially be used to address the soil and groundwater contamination identified in the risk assessment stage.

Assessment of Soil Remediation Options – Ex-situ Techniques

Bulk excavation and subsequent Landfill

8.3 The Landfill Directive sets out to limit landfilling of waste to a minimum as defined by EC legislation. The Landfill Directive precludes the bulk landfilling of contaminated soils unless there is no other option and even then, pre-treatment would be necessary.

8.4 One implication of the Landfill Directive is to limit the number of Landfills able to take contaminated wastes including contaminated soils.

8.5 It is considered that excavation and landfilling of contaminated soil at the site would have the following negative impacts:

- Contrary to the Landfill Directive and Sustainable Development;
- Potentially large excavation and landfilling with commensurate nuisance (e.g. lorry movements in and out of the site); and
- Materials used to in-fill the excavation could have a significant but uncertain influences on local groundwater movement.

8.6 Overall, bulk excavation and landfilling alone are not considered practical, cost-effective or the best available option. A certain degree of excavation and landfilling may be considered appropriate for materials which cannot be practically treated (e.g. if it contains asbestos).

8.7 It is considered unlikely that disposal to landfill of excavated soils at the site could be applied in a cost-effective manner.

Cover Systems

8.8 A surface cover system could be utilised in order to create a physical barrier between the contamination and the surface. In particular this would significantly prevent direct contact with contaminated soils although vapours could theoretically migrate from the underlying soil to the surface unless some type of 'break' layer was introduced (such as a capillary break or a membrane). This would potentially reduce or mitigate any risk of leaching of contamination in soils within the unsaturated zone. However, fluctuating groundwater levels beneath the site could mobilise or leach contamination associated with the 'smear' zone. In addition, water emanating from any impermeable cover would need capturing and diverting away from the local area if this is not to impact groundwater levels locally.

Excavation and Ex Situ On Site Treatment

8.9 Hotspots of contaminated soils could be excavated, treated on site and then re-utilised as acceptable back-fill. Provided this is undertaken in an appropriate manner then this is consistent with the Landfill Directive and the concepts of sustainable development. However, any bulk excavation would require careful consideration with respect to measures for controlling environmental impact particularly the mobilisation of contaminants into surface run-off, groundwater and the Sough Dyke. The following summarises methods of treatment that could be utilised.

Biophysical Treatment

8.10 Biophysical treatment involves processing the contaminated soils (to remove oversized material which can be crushed and incorporated into the treatment system where appropriate). The processing also results in homogenisation of the material making it easier to treat and allowing reliable (statistical) monitoring.

8.11 Biophysical treatment is flexible (eg, it can be applied to a range of contaminants and contaminant mixtures) but it does require a certain amount of time and space. In particular biochemical treatment applied ex-situ can easily and reliably be monitored and validated. Containment of run-off or leaching during treatment can be engineered.

8.12 Biophysical treatment is most applicable to remediation of organic compounds (TPH, BTEX and MTBE). Bioremediation is not considered feasible for the site due to the presence of tar material (long-chain length hydrocarbons and phenol). In addition,

bioremediation would not significantly reduce the concentration of heavy metals and benzo(a)pyrene to acceptable levels.

Physcio-chemical Techniques

8.13 Stabilisation techniques such as cementitious fixation is where cement is mixed with contaminated soil and this physically and/or chemically reduces the mobility or availability of the contaminants.

8.14 Cementitious processes require intensive (relatively expensive) mixing, treatment and additives and can have negative environmental impacts such as volatilisation of contaminants into the atmosphere (eg, due to elevated soil temperatures during treatment caused by lime hydration, etc). Whilst these environmental impacts can be managed/contained, this is at a significant cost with programme implications.

8.15 It is considered unlikely that physico-chemical treatment of excavated soils at the site could be applied in a cost-effective manner.

Soil Washing

8.16 Contaminated soils are excavated, then processed to remove oversized material and then washed with an aqueous solution (may include additives) to separate the soil into a coarse fraction and a fines and washings 'sludge'. The aim is to decontaminate the coarse fraction so it is suitable for re-use, leaving the fines and washings concentrated with the contaminants.

8.17 It is considered unlikely that soil washing would be an effective remediation technique at the site.

Assessment of Soil Remediation Options – In-situ Techniques

8.18 A range of in-situ techniques could be applied at the site. These techniques tend to be more expensive than ex-situ techniques and more applicable to deeper ground contamination where there is less heterogeneity of contaminant distribution than is likely in the shallower levels of the unsaturated zone. In-situ treatment can be an attractive option on active sites as the technique can result in reduced disturbance to commercial activities. In-situ techniques may also minimise the environmental impacts associated with bulk excavation.

Biophysical Treatment

8.19 In-situ bio-stimulation involves the stimulation of naturally occurring organisms in order to increase biodegradation of organic contaminants. This is achieved by the

infiltration/injection of water based solutions through contaminated soils into groundwater. Active treatment involves the re-circulation of groundwater, by pumping and re-injection into the source area. Passive systems do not involve pumping or re-injection.

8.20 Degradation rates are variable depending on a large number of site specific and chemical specific, physical, chemical and biological factors. Degradation of these chemical contaminants will further be influenced by their distribution and concentration across the site.

8.21 The presence of NAPL impacts the rate of biodegradation. Where NAPL is present, water-availability, nutrient transfer and gas transfer is limited to the surface of the oil matrix thus limiting overall mass reduction rates.

8.22 The advantages of in-situ biological treatment include its compatibility with natural processes and the relatively low impact upon environmental receptors during treatment.

8.23 It is considered unlikely that that application of in-situ bioremediation at the site could be applied in a cost-effective manner.

Chemical Treatment

8.24 In-situ chemical treatment techniques generally depend upon the chemical oxidation of the contaminants in-situ. An example is Fenton's Reagent (concentrated hydrogen peroxide solution with iron catalyst in a polyphosphate buffer). However, such a technique is unproven on a large scale due to the following key factors:

- Chemical oxidation is difficult to control and complete within the ground. Non-contaminant compounds (organic and inorganic) are oxidised as well as the contaminants. Contaminants that are only partially oxidised are likely to be much more mobile because they will be more soluble;
- The techniques will partially 'sterilise' the ground having a potentially negative impact upon local natural attenuation processes;
- Targeting the reactants is very difficult particularly in low-permeability or variable strata; and
- Off gases are produced and may require containment.

- Overall control of such large scale 'bucket chemistry' is extremely difficult and there are possible health and safety risks to operatives and uncertain but likely negative impacts upon Controlled waters.

8.25 It is considered unlikely that that application of in-situ chemical treatment at the site could be applied in a cost-effective manner.

Assessment of Groundwater Remediation Options

8.26 Based on the results of the DQRA, although groundwater contamination is present in shallow groundwater this is not considered significant due to the low sensitivity of the underlying aquifer, the absence of contamination in the Sough Dyke and the results of the assessment demonstrating that there will be no impact to the Barnsley Canal.

8.27 However, some treatment of groundwater encountered in excavations during groundworks on site may be required. It is likely that this will involve storage of contaminated water on site prior to discharge in order to ascertain the nature and extent of any contaminants. Treatment options are likely to involve flocculation and removal of contaminated sediment and the removal of free and dissolved phase product via a Granulated Active Carbon (GAC) filter. The likely outfall for treated groundwater is via discharge to the local foul sewerage network subject to meeting regulatory approvals. A method statement for dealing with contaminated ground water will be provided by the contractor prior to works starting.

Asbestos Containing Material

8.28 The asbestos contamination is currently covered by hardstanding. Future redevelopment of the site will expose the asbestos contaminated material. Therefore, remediation is required during future earthworks

8.29 The most appropriate remedial approach would be to minimise the potential for exposure between site workers, members of the public using the site, nearby residents and the future commercial occupants from asbestos contamination.

8.30 The only viable remediation method is excavation and either burial on site in a dedicated and clearly recorded area or disposal to landfill.

8.31 For large volumes of asbestos containing soils, burial on site is the preferred remediation method as this will ensure best practice and robust methods not entailing excessive cost and minimise the negative environmental impacts of the remediation itself. However, should the building programme or future liability issues restrict on

site works, the material will be removed from site by a licensed waste carrier for disposal at a permitted waste facility.

8.32 It is a requirement under the Control of Asbestos Regulations 2012 (Regulation 19) to monitor airborne fibre levels if it suspected that air concentrations might exceed the control limit of 0.1 f/ml.

Integrated Approaches

8.33 An integrated approach for remediation is required at the site as no one technique (including 'dig and dump') will effectively address the environmental issues. By integrating the remediation techniques used at the site this would (a) maximise the benefit of remediation using best practice and robust methods not entailing excessive cost and (b) minimise the negative environmental impacts of the remediation itself.

9 OUTLINE OF PROPOSED REMEDIATION SCHEME

Introduction

9.1 Whilst the risk assessment was completed in accordance with standard practices and Environment Agency guidelines, the models used are conservative and professional judgement is required to determine remedial requirements. Therefore, it is recommended that prior to redevelopment, a 'reasonable' approach for remediation is agreed with the regulatory authorities.

9.2 Note that this outline remediation proposal is for discussion only and does not include any site development issues including those issues associated with temporary or permanent site drainage, building or geotechnical requirements.

Remediation Scheme

9.3 On the basis of consideration of the issues highlighted in this report, the following remediation scheme is proposed:

1. Formally agree the final scheme with the EA and BMBC including formulation of H&S documentation and methods, Environmental Permits, details of monitoring (groundwater, surface waters, soils, air, monitoring and validation).
2. Remove all drainage conduits, tanks, foundations and underground structures, and crush for reuse on-site. Any free product or NAPL encountered in drainage conduits will be carefully transferred into containers for removal off-site subject to waste classification and duty of care requirements.
3. During the excavation works materials will be separated based on previous laboratory testing and a visual assessment. In addition, soil samples will be collected from the base and sides of excavations for laboratory analysis to validate the works (as per Table XI). Asbestos remediation is detailed further in a separate section below.
4. Groundwater encountered during earthworks will be assessed by an appropriately qualified person and treated by separation of sediment and free product and, if required, removal of dissolved phase contamination. The disposal point for treated groundwater is likely to be foul sewers connected to the site subject to consent by the regulatory authorities and as detailed within Environmental Permits.

5. A robust materials management plan will be in place. Excavated material will be segregated into stockpiles comprising natural materials that are suitable for use, made ground that is likely to be suitable for use subject to testing, made ground that is unsuitable for use and untreatable materials including drums and wood etc. Unsuitable materials will be segregated into those that can be remediated for future use and those for disposal off site.
6. The stockpile groups will be defined based on visual and olfactory means supported by laboratory testing. The suitability of material will be based on the remedial targets outlined in this report.
7. If required, ex-situ remediation of the petroleum hydrocarbon impacted material prior to reuse on site. Treatment will incorporate appropriate odour control and the materials will be validated by chemical testing.
8. Placement of material considered a potential risk to human health at a depth of greater than 1m below the final ground level, where appropriate.
9. Off-site disposal of contaminated material that is not treatable, where necessary. Certain materials may require pre-treatment prior to disposal.
10. Recompaction and validation of engineered fill to form a base beneath buildings, roads and parking areas.
11. Validation of site won material used to form shallow soil less 450mm below areas of public open space.

9.4 For material disposed off site as waste then test certificates, waste haulage and transfer notes (including weighbridge tickets) will be required. This will confirm the nature, quality and quantity of the waste that has been disposed off-site. If disposal is required, this information is to be provided as part of the relevant validation report documents.

Remediation of Asbestos Contaminated Soil

9.5 This section describes the general methodology for conducting excavation, disposal and backfilling works within the areas of the site containing asbestos. Method statements provided by the contractors for conducting the remediation works will be provided as required.

9.6 The one quantification test carried out on soils containing asbestos has indicated that it is present at very low concentrations in made ground and will be excavated as part

of the proposed earthworks. However, additional areas containing greater concentrations of asbestos in soil cannot be discounted. Appropriate material management controls and health and safety precautions will be adopted where excavation of material containing asbestos is proposed as discussed below.

9.7 The objective of the asbestos remediation is to screen earthworks samples and segregate excavated soils containing elevated concentrations of fibres. This material will be placed and clearly documented in a validation report. To minimise disturbance of asbestos fibres, the preferred placement location is beneath buildings and hardstanding in areas where future disturbance will not take place. The asbestos contaminated material will be covered with a barrier to alert any future groundworkers and clearly document the location of the material.

9.8 Where pieces of ACM are encountered, these will be 'hand-picked' and placed in a hazardous waste disposal bag and then double bagged for off-site disposal to a suitably licenced waste facility.

9.9 Earthworks will be carried out in general accordance with CAR-SOIL (Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance) and will comprise the following activities:

1. Pre-start meeting. All operatives will be issued with dust masks and appropriate PPE.
2. Establish clearly defined and signed stockpile areas.
3. Excavation of made ground in the vicinity of the asbestos contamination. During excavation dust suppression will be employed in the form of a water mist. Dust generation and levels will be carefully monitored and controlled throughout site operations.
4. Dust monitoring throughout the works. This will include visual checks and use of a portable, hand held dust monitors. If conditions cause dust generation that cannot be suppressed, site works will be suspended until such time that dust is no longer being released.
5. Movement of excavated material to a stockpile area for testing. Two stockpiles of the excavated material will be formed; one stockpile will comprise potential asbestos contaminated soil and the other stockpile will comprise potentially non-asbestos contaminated soil. The stockpiles will be screened for asbestos

containing material and asbestos fibres with quantification testing as required (outlined below).

6. The stockpiles will be kept damp and placed in a designated area lined and securely covered with polythene sheets or similar. Movement and disturbance of material and stockpiles will be kept to a minimum with excavated material being carefully placed in its corresponding stockpile with no further movement or reshaping.
7. Material tested as negative for asbestos will be reused as appropriate. Material that tests positive, undergoes further quantification testing and contains an elevated concentration of asbestos (i.e. >0.001%) will be placed at depth and covered with suitable material to form a cover system. In contrast to this, material that tests positive and undergoes further quantification testing and contains a very low abundance of asbestos will be subject to further risk assessment prior to re-use.
8. Validation testing will be completed on the base and sides of excavations. Monitoring should demonstrate that there has not been significant dust generation.
9. Material containing >0.001% concentrations of asbestos fibres will be placed in a designated area with the top of the material at least 1.0m below the finished ground level and below or distant from any proposed service runs such as surface water drains. The asbestos contaminated material will be compacted with strict dust control and with all plant washed prior to removal from the excavation. A warning barrier will be placed across the top of the contaminated material and the excavation backfilled to achieve the final ground level.
10. Preparation of a final remediation validation report documenting the works. The report will include a description of works and the extent of excavations. In addition, monitoring should demonstrate that there has not been significant dust generation. Once validation has confirmed that asbestos contaminated material has been removed from site or covered by an impermeable barrier the validation report should be submitted to the relevant authorities and the area released for development.

9.10 Earthworks involving material containing asbestos will need to minimise potential generation of airborne fibres. Appropriate environmental controls will be established by the contractors working on the site. Appropriate method statements and risk assessments for all potentially hazardous activities will be prepared by the contractor

as necessary prior to undertaking works at the site. Specifically, these method statements and risk assessments will detail procedures to be put in place to control the potential release of asbestos fibres during earthworks at the site. It is considered likely that measures including use of appropriate PPE, good hygiene practices together with damping down of haul roads, temporary stockpiles and excavations will be required. As necessary, working methods will be adapted so that there are no significant issues relating to dust or noise including statutory nuisance as the works progress.

Site Induction

9.11 All workers at the site will need to undertake a site induction that informs them of the potential presence of asbestos and safe methods of working that need to be employed. The induction and tool box talks will also need to ensure that workers at the site are aware of the asbestos management protocols that have been put in place at the site.

Construction Arisings

9.12 Given the site's historic use contaminated material including asbestos fibres may be present in construction arisings. This material will need to be assessed by a competent person and, if required, remediated in line with the options present above. For arisings to be retained on site, the material will require testing to ensure it is suitable for use as summarised in Table XI.

Site Won Demolition Materials

9.13 CIRIA publication C733, Asbestos in soil and made ground: a guide to understanding and managing risks, advises: "It is difficult (and sometimes not possible) to ensure that all asbestos is removed prior to demolition. Building rubble is liable to contain ACM, and may contain free fibres."

9.14 Therefore, notwithstanding modern demolition procedures and asbestos surveys, site-won demolition material may contain residual asbestos fibres and/or pieces of asbestos containing material. This material will need to be assessed by a competent person and, if required, remediated in line with the options present above. For demolition material to be re-used on site, the material will require testing to ensure it is suitable for use as summarised in Table XI.

Unidentified Contamination

9.15 In the event of significant unexpected contamination being encountered, the works will be halted until:

- A suitably qualified person is able to assess the situation;
- The regulatory authorities are consulted; and
- An agreed plan is put in place to deal with the contamination.

Piling Methods and Environmental Constraints

9.16 Post earthworks and remediation, piling will penetrate made ground and natural material containing potential contaminants. In particular, piling will pass through contaminated material in the vicinity of the Markets Basement hotspot.

9.17 Formal approval of the method of piling will be required from the Environment Agency due to the potential risk of contaminating the underlying minor aquifer. The use of continuous flight auger and rotary piling is likely to be acceptable for the development. Driven or displacement piles are not considered appropriate as contaminated material may be smeared along the length of the pile.

Remediation Criteria

9.18 The remediation criteria to be used for the validation of the remedial works will be the relevant Remediation Targets presented in this report, LQM S4UL or the C4SL values for the appropriate land use or derived Site Specific Assessment Criteria as required.

9.19 Remedial targets for groundwater including treated groundwater to be discharged to surface water / foul sewer will be based on limits of discharge permits and/or Environmental Quality Standards (EQS) as below:

- LQM/CIEH S4UL's for Human Health Risk Assessment, 2015;
- SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination, DEFRA, 2014; and
- EQS - The Water Framework Directive (Standards and Classification) Directions (England and Wales), 2015.

Validation of Materials

9.20 The proposed strategy for monitoring and validation is discussed below and summarised in Table XI. All monitoring, sampling and reporting will be undertaken by experienced and suitably qualified managers, scientists and engineers.

9.21 Sampling and testing of materials on site will be carried out in accordance with best practice and guidance including Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG) *Verification Requirements for Cover Systems* as appropriate. The minimum testing suite for materials is as follows:

- **For treated groundwater**: speciated TPHCWG (incl BTEX), PAHs, phenol, pH and any other testing required by Environment Permit / Water Authority for discharge to sewer;
- **Surface water**: speciated TPHCWG (incl BTEX), PAHs, phenol, pH;
- **Remediated material**: detailed testing for the contaminants of concern; and
- **Crushed demolition material and construction arisings**: asbestos screen and ID followed by asbestos quantification (<0.001%) as required.

9.22 As part of the earthworks, site-won materials will arise that are either potentially suitable or unsuitable for use and a determination based upon a visual and olfactory procedure backed up by laboratory testing will be in place as discussed below.

Validation of Site-won Materials - (Earthworks and Remediation)

9.23 Material excavated at the site that is destined to be deposited elsewhere on site will require validation sampling as detailed in Table XI. A robust materials management plan will be in place to ensure material excavated and placed elsewhere on site is suitable for use and will include segregation of materials including:

- Made ground that is suitable for use;
- Made ground that is not suitable for use, segregated further into material suitable for treatment and material for disposal off site;
- Natural ground; and
- Un-treatable materials e.g. drums, wood etc.

9.24 Samples of soils material will be tested for the following as a minimum; speciated PAHs (USEPA 16), SOM%, pH, inorganics (arsenic, cadmium, chromium, chromium VI, copper, lead, mercury, nickel and zinc), TPHCWG (C5-C44 with aliphatic and aromatic

banding), phenol, water soluble sulphate (2:1 extract), asbestos screen and ID (quantification to <0.001% as required).

Validation of Site-won Materials – Crushed Demolition Materials

9.25 Site-won crushed demolition materials and arising's may be potentially suitable for use as a coarse granular layer on site. All such materials will be suitably validated prior to use i.e. stockpile sampling or a sampling grid will be established to obtain validation samples to ensure the material is suitable for use. Material should be validated as outlined in Table II.

9.26 Samples of crushed demolition material will be tested for the following as a minimum; pH, water soluble sulphate (2:1 extract), asbestos screen and ID (quantification to <0.001% as required).

Validation of Remedial Excavations

9.27 The excavation area should be visually inspected and noted to be dry before backfilling. In addition, the sides and base of the excavation should be sampled and tested to validate the remediation. It is proposed that a validation sample is collected every 20m along the edge of the excavation and on a 20m grid on the base of the excavation or a minimum of 5 validation samples per excavation (1 per base and 1 per face of excavation).

9.28 Validation samples should be tested for the relevant contaminants of concern by a UKAS accredited laboratory.

Validation of Material Beneath Public Open Space / Landscaping

9.29 Site-won soils (made ground and natural soils) and arisings may be potentially suitable for use in landscaping / POS. Following the earthworks and remediation activities, validation of the POS / landscaping within the top 450mm bgl will be required. If site-won material is not suitable, then imported clean fill and topsoil will be required to form a cover system in areas of landscaping / POS. The origins and characteristics of the material should be documented in the validation report.

9.30 Site-won and imported materials will need to be validated (e.g. validation sampling grid) as outlined below and in Table XI to ensure that they are suitable for use.

9.31 Samples of site-won or imported material will be tested for the following as a minimum; speciated PAHs (USEPA 16), SOM%, pH, inorganics (arsenic, cadmium, chromium, chromium VI, copper, lead, mercury, nickel and zinc), TPHCWG (C5-C44

with aliphatic and aromatic banding), asbestos screen and ID (quantification to <0.001% as required).

9.32 The thickness of the cover system should be validated to ensure that there is the required depth of cover. This will most likely be accomplished through digging a grid of trial holes to allow measurement of its depth by a measuring staff with a photographic record.

Monitoring

Treated Groundwater Monitoring

9.33 Any groundwater encountered during excavation works should be assessed for visual or olfactory signs of contamination and if required, treated by collection and pumping through a water treatment plant.

9.34 Treated groundwater pumped from the excavation should be monitored following guidance from the Environment Agency and will be documented within the Environmental Permit.

Surface Water Monitoring Plan

9.35 It is anticipated that the remedial activities will not significantly impact the Sough Dyke. To guard against unexpected impact to the Sough Dyke, a daily visual inspection of the Sough Dyke, in the vicinity of the site, should be carried out and the presence or absence of visual contamination noted. In addition, a weekly water sample should be collected from monitoring points upstream and downstream of the site and tested for the contaminants of concern by a UKAS accredited laboratory.

9.36 In the unlikely event that an impact is identified, the regulatory authority should be notified and measures put in place to correct the situation.

Shallow Groundwater Monitoring Plan

9.37 Any groundwater encountered during excavation works should be assessed for visual or olfactory signs of contamination and if required treated by collection and pumping through a water treatment plant.

9.38 Monitoring boreholes should be used to monitor groundwater quality down hydraulic gradient of the hotspot should be used to monitor groundwater quality.

9.39 Shallow groundwater samples should be recovered and tested on a monthly basis during remediation and following completion of the works. Groundwater samples

should be tested for the contaminants of concern by a UKAS accredited laboratory. In addition, the physical parameters associated with the borehole should be recorded and reported within the final validation report.

Monitoring and Validation of Ex-situ Remediation

9.40 Periodic monitoring of the remediation materials will comprise 1 representative sample per 250m^3 (Table XII). Monitoring and validation samples will be tested for the contaminants of concern by a UKAS accredited laboratory.

Air Emission Monitoring

9.41 Prior to starting remedial works, it will be necessary to establish environmental monitoring positions around the perimeter of the site to monitor and manage dust levels to appropriate levels throughout the works. It will also be necessary to establish a site compound with welfare facilities.

9.42 Dust monitors will be installed at the site and monitoring will be undertaken before and during the development. During the works dust monitoring will be carried out on a monthly basis and more often during dry periods and compared to background levels. If significantly elevated dust levels are detected dust control measures will be implemented.

9.43 Air monitoring will be completed prior to earthworks to set a baseline for dust and possible asbestos fibres. This baseline will then be used to ensure that site works do not increase the background levels.

9.44 Records will need to be maintained for all of the environmental monitoring activities undertaken throughout the works. Environmental monitoring will be undertaken in general accordance with the Society of Brownfield Risk Assessors (SoBRA) *Airborne Asbestos Fibre and Dust Monitoring Protocols for Earthwork Activities at Brownfield Sites* and CAR-SOIL.

9.45 Odours will be monitored on a daily basis as per Environment Agency 'Internal Guidance for the Regulation of Odour at Waste Management Facilities' July 2002 VERSION 3.0, and documented in the validation report.

TABLE XII - OUTLINE OF PROPOSED MONITORING AND VALIDATION			
Material		No. Samples	Rationale
Imported Material – Clean Soils	Post-earthworks	1 sample per 250m^3 if homogenous or 1 sample per 100m^3 if relatively inhomogeneous	To validate the material prior to redevelopment.
Site-won – Crushed Demolition Material	Prior to or during earthworks	1 sample per 500m^3	
Site-won Excavated Material - Soils	During earthworks	1 sample per 250m^3	
Validation of Public Open Space	Post-earthworks	Validation sample on a 25m grid taken within top 0.3m below final ground level.	
Treated Material	During remediation	1 sample per 250m^3	To validate the material prior to reuse.
Remediation Excavations	During remediation	Validation sample every 20m along the edge of the excavation and on a 20m grid on the base of the excavation or minimum of 5 validation samples per excavation (1 per base and 1 per face of excavation).	
Construction Arisings	Post-earthworks	1 sample per 250m^3	
Air Emissions	During remediation and earthworks	Monitors for dust, EA guidance for odours.	To monitor dust and odour.
Treated Groundwater		Monitoring to satisfy EA guidance and discharge consent.	To ensure compliance with discharge consent.
Groundwater	During remediation	Monthly samples.	To establish betterment in

	Post remediation	Monthly samples for 3 months.	groundwater quality.
Surface water	During Remediation	Weekly samples and inspections	To ensure no impact on Sough Dyke
Bioremediation and Stabilisation	Post remediation	1 sample per 250m^3	

10 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

10.1 The detailed risk assessment has identified a potential significant risk to human health from PAHs in shallow made ground.

10.2 Asbestos fibres were identified in seven samples across the site. One sample was submitted for detailed quantification and the fibre concentration recorded was <0.001%. Therefore, asbestos fibres in soil may present a significant risk to human health at the site.

10.3 Results from the detailed quantitative risk assessment indicate that, when considering the Sough Dyke as the most sensitive receptor there is a significant risk to the environment from elevated concentrations of carbazole, benzene, naphthalene and xylene in soil. However, monitoring of the Sough Dyke has demonstrated that it is not being impacted by contamination beneath the site.

10.4 Results from the detailed quantitative risk assessment when considering the Barnsley Canal as the most sensitive receptor indicate there is no significant risk to the environment from soil and groundwater contamination at the site.

Recommendations

10.5 Based on the all of the available information, remediation is not recommended at the site to protect the environment. However, there is a potential risk to human health from PAHs and asbestos in shallow made ground and mitigation, in the form of contaminated soils being placed at depths of greater than 1m below finished levels or beneath buildings or hardstanding, is recommended. This approach should be agreed in advance with the Environment Agency and Local Authority Contaminated Land Officer.

Validation Report

10.6 A validation report detailing the results of the remediation work should be prepared on the completion of the site works. The report should demonstrate that the agreed remediation strategy has been implemented and that the necessary treatment of soil and groundwater has led to:

- no significant risk to human health of future occupiers of the site;
- a betterment in groundwater quality; and

- no impact to the water quality of the Sough Dyke.

10.7 The report will include:

- a description of the earthworks and remediation;
- validation of thickness of 450mm of the POS/landscaping;
- results of laboratory chemical analysis for validation testing and monitoring during and post remediation;
- certification of any imported soils and coarse materials (including appropriate analysis); and
- waste disposal documentation to demonstrate 'duty of care'.

10.8 The validation report should be submitted to the relevant authorities.

APPENDIX I

Standard Terms and Conditions and Limitations to Reports

STANDARD TERMS AND CONDITIONS AND LIMITATIONS TO REPORTS

This Report is provided for the stated purpose and for the sole use of the client in accordance with the Terms and Conditions of Appointment under which the services were performed. The Report is confidential to the client and no other warranty, expressed or implied, is made as to the professional advice included in the Report or any other services provided by Wardell Armstrong LLP. This Report may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of Wardell Armstrong LLP.

The conclusions and recommendations contained in this Report are based upon information provided by others including details supplied by the client and/or professional advisors on the assumption that all relevant information from whom it has been requested and/or supplied is accurate. Information so provided and/or supplied has not been verified independently by Wardell Armstrong LLP, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by Wardell Armstrong LLP in providing the services are outlined in this Report. The work described in this Report is based on the conditions and information as stated at the date the Report was completed. The scope of this Report and the services are accordingly limited by these circumstances. The findings outlined in the Report together with any opinions expressed and recommendations made are considered to be valid and appropriate at the time of preparation and for the specific purpose or purposes intended. Whilst a walk over site visit may have been carried out as part of the work this has been limited to observations only and no other physical investigations, sampling and testing work has been carried out as part of this work.

Wardell Armstrong LLP disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report which may come or be brought to Wardell Armstrong LLP's attention after the date of the Report. Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Where any site observations have been carried out, these have been restricted to a level of detail required to meet the stated objectives of the services. The results from any site observations made may vary and further confirmatory work should be made after the issuance of this Report. Wardell Armstrong LLP does not guarantee or warrant any estimates or projections contained in this Report.

A P P E N D I X I I

CLEA UK Worksheet

STEP 5: RESULTS

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		Ratio of ADE to relevant Health Criteria Value			Soil Assessment Criteria			SAC Flag	Soil Saturation Limit	Pathway Contributions (%)										
		oral HCV	inhal HCV	Combined	oral HCV	inhal HCV	Combined	Current SAC used for determining pathway contributions		direct soil ingestion	sum of consumption of homegrown produce and attached soil	dermal contact (indoor)	dermal contact (outdoor)	inhalation of dust (indoor)	inhalation of dust (outdoor)	inhalation of vapour (indoor)	inhalation of vapour (outdoor)	oral background	inhalation background	Total
Number	Chemical	(dimensionless)	(dimensionless)	(dimensionless)	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	(unitless)	mg kg^{-1}	%	%	%	%	%	%	%	%	%	%	%
1	Benzene	0.00	1.00	1.00	**NR**	4.86E+03	4.86E+03	Combined	4.99E+03	0.00	0.00	0.00	0.00	0.80	0.00	97.13	2.07	0.00	0.00	100.00
2	Phenol	0.00	1.00	1.00	**NR**	**9.31E+05**	**9.31E+05**	Combined	1.84E+05	0.00	0.00	0.00	0.00	21.45	0.00	70.23	2.60	0.00	5.71	100.00
3	Naphthalene	0.00	1.00	1.00	**NR**	**2.63E+04**	**2.63E+04**	Combined	4.35E+02	0.00	0.00	0.00	0.00	7.04	0.00	88.12	0.19	0.00	4.65	100.00
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STEP 5: RESULTS

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		Ratio of ADE to relevant Health Criteria Value			Soil Assessment Criteria			SAC Flag	Soil Saturation Limit	Pathway Contributions (%)										
		oral HCV	inhal HCV	Combined	oral HCV	inhal HCV	Combined	Current SAC used for determining pathway contributions		direct soil ingestion	sum of consumption of homegrown produce and attached soil	dermal contact (indoor)	dermal contact (outdoor)	inhalation of dust (indoor)	inhalation of dust (outdoor)	inhalation of vapour (indoor)	inhalation of vapour (outdoor)	oral background	inhalation background	Total
Number	Chemical	(dimensionless)	(dimensionless)	(dimensionless)	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	(unitless)	mg kg^{-1}	%	%	%	%	%	%	%	%	%	%	%
1	Benzo[a]pyrene (C4SL child)	0.02	1.00	NR	1.75E+04	2.75E+02	**NR**	Inhal	5.46E+00	0.00	0.00	0.00	0.00	95.86	0.00	0.06	4.08	0.00	0.00	100.00
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STEP 5: RESULTS

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		Ratio of ADE to relevant Health Criteria Value			Soil Assessment Criteria			SAC Flag	Soil Saturation Limit	Pathway Contributions (%)										
		oral HCV	inhal HCV	Combined	oral HCV	inhal HCV	Combined	Current SAC used for determining pathway contributions		direct soil ingestion	sum of consumption of homegrown produce and attached soil	dermal contact (indoor)	dermal contact (outdoor)	inhalation of dust (indoor)	inhalation of dust (outdoor)	inhalation of vapour (indoor)	inhalation of vapour (outdoor)	oral background	inhalation background	Total
Number	Chemical	(dimensionless)	(dimensionless)	(dimensionless)	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	(unitless)	mg kg^{-1}	%	%	%	%	%	%	%	%	%	%	%
1	Benzo[a]pyrene (C4SL child)	0.02	1.00	NR	1.82E+04	2.86E+02	**NR**	Inhal	5.46E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100.00
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STEP 5: RESULTS

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		Ratio of ADE to relevant Health Criteria Value			Soil Assessment Criteria			SAC Flag	Soil Saturation Limit	Pathway Contributions (%)										
		oral HCV	inhal HCV	Combined	oral HCV	inhal HCV	Combined	Current SAC used for determining pathway contributions		direct soil ingestion	sum of consumption of homegrown produce and attached soil	dermal contact (indoor)	dermal contact (outdoor)	inhalation of dust (indoor)	inhalation of dust (outdoor)	inhalation of vapour (indoor)	inhalation of vapour (outdoor)	oral background	inhalation background	Total
Number	Chemical	(dimensionless)	(dimensionless)	(dimensionless)	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	(unitless)	mg kg^{-1}	%	%	%	%	%	%	%	%	%	%	%
1	Benzo[a]pyrene (C4SL child)	0.02	1.00	NR	**4.22E+05**	**6.64E+03**	**NR**	Inhal	5.46E+00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	98.62	0.00	0.00	100.00
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STEP 5: RESULTS

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		Ratio of ADE to relevant Health Criteria Value			Soil Assessment Criteria			SAC Flag	Soil Saturation Limit	Pathway Contributions (%)										
		oral HCV	inhal HCV	Combined	oral HCV	inhal HCV	Combined	Current SAC used for determining pathway contributions		direct soil ingestion	sum of consumption of homegrown produce and attached soil	dermal contact (indoor)	dermal contact (outdoor)	inhalation of dust (indoor)	inhalation of dust (outdoor)	inhalation of vapour (indoor)	inhalation of vapour (outdoor)	oral background	inhalation background	Total
Number	Chemical	(dimensionless)	(dimensionless)	(dimensionless)	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	(unitless)	mg kg^{-1}	%	%	%	%	%	%	%	%	%	%	%
1	Benzene	0.00	1.00	1.00	**NR**	**6.08E+05**	**6.08E+05**	Combined	4.99E+03	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100.00
2	Phenol	0.00	1.00	1.00	**NR**	**4.09E+06**	**4.09E+06**	Combined	1.84E+05	0.00	0.00	0.00	0.00	94.29	0.00	0.00	0.00	0.00	5.71	100.00
3	Naphthalene	0.00	1.00	1.00	**NR**	**3.56E+05**	**3.56E+05**	Combined	4.35E+02	0.00	0.00	0.00	0.00	95.35	0.00	0.00	0.00	0.00	4.65	100.00
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APPENDIX III

Remedial Target Worksheets

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Ali C8-C10			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Ali C8-C10**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	4.15E+01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	3.02E+04	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.43E+02**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.75E+02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C8-C10**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2	**Based on site investigation data**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.83E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Ali C8-C10		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		5.8	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	6.04E+02	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	1.61E+03	fraction
Decay rate used	λ	4.30E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	7.93E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	1.05E-02	mg/l

Remedial Targets

Level 3 Remedial Target		**No impact**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		No impact	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**5**	**m**	
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	2.00E-02	fraction
Organic carbon partition coefficient	Koc	3.02E+04	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	6.04E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

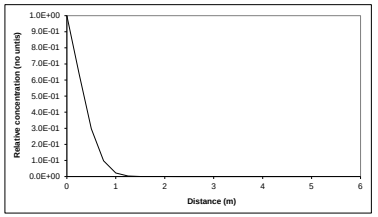
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.02E-02
0.3	6.38E-01	6.53E-03
0.5	2.98E-01	3.05E-03
0.8	9.78E-02	1.00E-03
1.0	2.20E-02	2.25E-04
1.3	3.34E-03	3.42E-05
1.5	3.39E-04	3.47E-06
1.8	2.28E-05	2.34E-07
2.0	1.02E-06	1.04E-08
2.3	1.58E-08	1.61E-10
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Ali C8-C10		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.20E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	6.04E+02	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	1.61E+03	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	2.28E-07	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	2.00E-02	fraction
Organic carbon partition coefficient	Koc	3.02E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	6.04E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

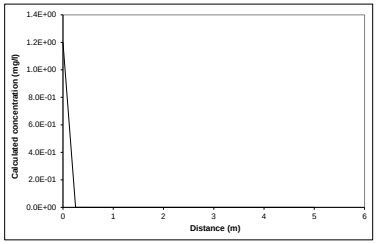
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.2E+00
0.3	1.66E-04
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Ali C10-C12			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Ali C10-C12**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	6.44E+01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	2.40E+05	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**4.31E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.16E+03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C10-C12**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.22E+03	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Ali C10-C12		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		7.2	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.31E+03	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	1.15E+04	fraction
Decay rate used	λ	6.03E-105	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.11E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	1.67E-03	mg/l

Remedial Targets

Level 3 Remedial Target	**No impact**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	No impact	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point	**5**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0** **0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.40E+05	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.31E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

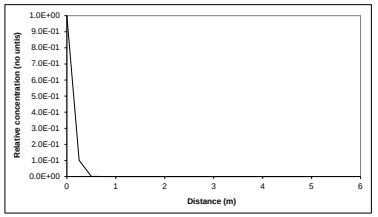
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.62E-03
0.3	1.01E-01	1.64E-04
0.5	7.35E-04	1.19E-06
0.8	2.97E-07	4.80E-10
1.0	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Ali C10-C12		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.00E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.31E+03	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	1.15E+04	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	3.20E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.40E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.31E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

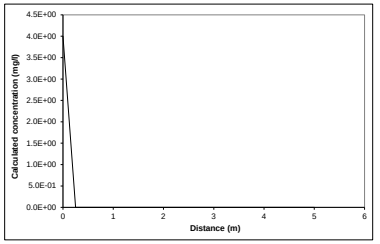
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	4.0E+00
0.3	0.00E+00
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Ali C12-C16			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Ali C12-C16**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.71E+02	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**9.65E+04**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.83E+04**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C12-C16**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		4.97E+04	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Ali C12-C16		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		3100	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.65E+04	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	2.57E+05	fraction
Decay rate used	λ	2.69E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	4.97E-08	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	3.21E-02	mg/l

Remedial Targets

Level 3 Remedial Target		**No impact**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		No impact	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**5**	**m**	
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.65E+04	l/kg

Define dispersivity (click brown cell and use pull down list)

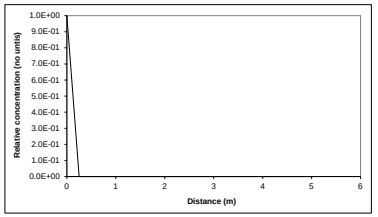
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	3.12E-02
0.3	0.00E+00	0.00E+00
0.5	0.00E+00	0.00E+00
0.8	0.00E+00	0.00E+00
1.0	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | Variable | Value | Unit | Source

Contaminant		Ali C12-C16		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.00E-02	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.65E+04	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | Variable

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	2.57E+05	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	1.43E-09	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.65E+04	l/kg

Define dispersivity (click brown cell and use pull down list)

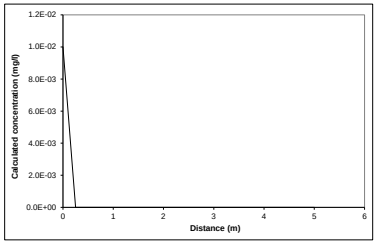
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E-02
0.3	0.00E+00
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Ali C16-C35			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Ali C16-C35**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.07E+03	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	5.75E+08	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.03E+07**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.17E+06**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C16-C35**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		5.32E+06	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Ali C16-C35		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		2640	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.03E+07	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	2.76E+07	fraction
Decay rate used	λ	2.51E-108	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	4.64E-10	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	2.55E-04	mg/l

Remedial Targets

Level 3 Remedial Target		**No impact**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		No impact	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**5**	**m**	
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.03E+07	l/kg

Define dispersivity (click brown cell and use pull down list)

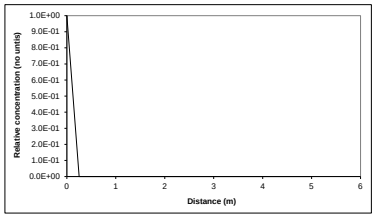
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	2.48E-04
0.3	0.00E+00	0.00E+00
0.5	0.00E+00	0.00E+00
0.8	0.00E+00	0.00E+00
1.0	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Ali C16-C35		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.00E-02	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.03E+07	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	2.76E+07	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	1.33E-11	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.03E+07	l/kg

Define dispersivity (click brown cell and use pull down list)

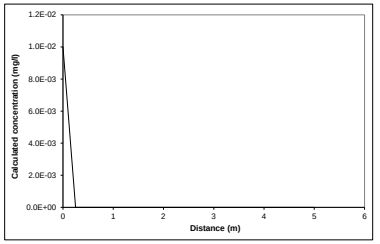
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}(x))^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E-02
0.3	0.00E+00
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Aro C8-C10			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aro C8-C10**		
Target concentration	**C_T**	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	2.53E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	1.58E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.85E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.44E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C8-C10**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.48E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aro C8-C10		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		18	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.85E+01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	7.69E+01	fraction
Decay rate used	λ	9.01E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.66E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	1.73E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**5.77E+00**	**fraction**
Calculated soil leachate concentration	Co	6.27E-01	mg/l

Remedial Targets

Level 3 Remedial Target	**2.97E+00**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	8.53E+01	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration C_{ED}/C_0	**1.73E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.58E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.85E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	6.09E-01
0.3	9.94E-01	6.05E-01
0.5	9.85E-01	6.00E-01
0.8	9.72E-01	5.92E-01
1.0	9.54E-01	5.81E-01
1.3	9.32E-01	5.68E-01
1.5	9.04E-01	5.50E-01
1.8	8.69E-01	5.29E-01
2.0	8.29E-01	5.05E-01
2.3	7.82E-01	4.76E-01
2.5	7.31E-01	4.45E-01
2.8	6.75E-01	4.11E-01
3.0	6.15E-01	3.75E-01
3.3	5.53E-01	3.37E-01
3.5	4.91E-01	2.99E-01
3.8	4.29E-01	2.61E-01
4.0	3.70E-01	2.25E-01
4.3	3.14E-01	1.91E-01
4.5	2.62E-01	1.59E-01
4.8	2.15E-01	1.31E-01
5.0	1.73E-01	1.06E-01

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | Variable | Value | Unit | Source

Contaminant		Aro C8-C10		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	3.30E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.85E+01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | Variable

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	7.69E+01	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	4.78E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.58E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.85E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

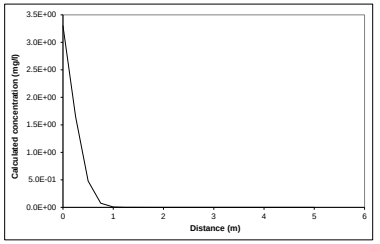
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	3.3E+00
0.3	1.65E+00
0.5	4.78E-01
0.8	7.51E-02
1.0	6.16E-03
1.3	2.58E-04
1.5	5.46E-06
1.8	3.02E-08
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Aro C10-C12			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aro C10-C12**		
Target concentration	**C_T**	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	7.22E-02	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	2.51E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**4.51E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.27E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C10-C12**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.33E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Aro C10-C12		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		11	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.51E+01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	1.21E+02	fraction
Decay rate used	λ	5.71E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.05E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	1.98E-02	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**5.04E+01**	**fraction**
Calculated soil leachate concentration	Co	2.43E-01	mg/l

Remedial Targets

Level 3 Remedial Target	**2.60E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.18E+03	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration (C_{ED}/C_0)	**1.98E-02**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.51E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

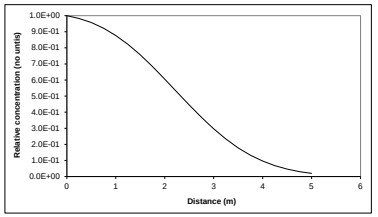
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.36E-01
0.3	9.83E-01	2.32E-01
0.5	9.57E-01	2.26E-01
0.8	9.22E-01	2.17E-01
1.0	8.77E-01	2.07E-01
1.3	8.21E-01	1.94E-01
1.5	7.56E-01	1.78E-01
1.8	6.84E-01	1.61E-01
2.0	6.05E-01	1.43E-01
2.3	5.25E-01	1.24E-01
2.5	4.45E-01	1.05E-01
2.8	3.68E-01	8.66E-02
3.0	2.96E-01	6.99E-02
3.3	2.33E-01	5.49E-02
3.5	1.78E-01	4.20E-02
3.8	1.33E-01	3.13E-02
4.0	9.61E-02	2.27E-02
4.3	6.77E-02	1.59E-02
4.5	4.63E-02	1.09E-02
4.8	3.07E-02	7.25E-03
5.0	1.98E-02	4.67E-03

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | **Variable** | **Value** | **Unit** | **Source**

Contaminant		Aro C10-C12		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	6.00E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.51E+01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | **Variable**

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	1.21E+02	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	3.03E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.51E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

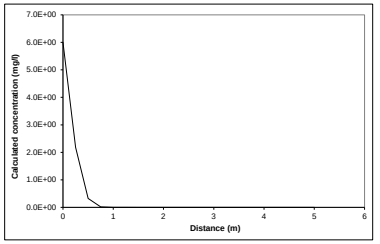
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	6.0E+00
0.3	2.19E+00
0.5	3.25E-01
0.8	1.78E-02
1.0	3.39E-04
1.3	2.20E-06
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Aro C12-C16			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aro C12-C16**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.26E-02	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	5.01E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**9.00E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.51E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C12-C16**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		4.64E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Aro C12-C16		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		11	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.00E+01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	2.41E+02	fraction
Decay rate used	λ	2.88E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	5.30E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.08E-05	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**4.81E+04**	**fraction**
Calculated soil leachate concentration	Co	1.22E-01	mg/l

Remedial Targets

Level 3 Remedial Target	**2.48E+04**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.23E+06	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point	**5**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration (C_{ED}/C_0)	**2.08E-05**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.00E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

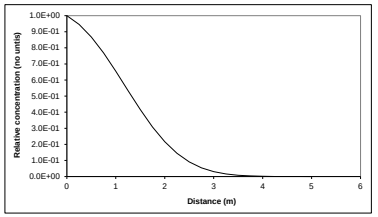
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.18E-01
0.3	9.45E-01	1.12E-01
0.5	8.67E-01	1.03E-01
0.8	7.69E-01	9.10E-02
1.0	6.55E-01	7.76E-02
1.3	5.34E-01	6.33E-02
1.5	4.16E-01	4.93E-02
1.8	3.08E-01	3.65E-02
2.0	2.17E-01	2.57E-02
2.3	1.45E-01	1.71E-02
2.5	9.11E-02	1.08E-02
2.8	5.43E-02	6.43E-03
3.0	3.05E-02	3.62E-03
3.3	1.62E-02	1.92E-03
3.5	8.09E-03	9.58E-04
3.8	3.81E-03	4.51E-04
4.0	1.69E-03	2.00E-04
4.3	7.04E-04	8.33E-05
4.5	2.76E-04	3.27E-05
4.8	6.04E-05	7.16E-06
5.0	2.08E-05	2.46E-06

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | **Variable** | **Value** | **Unit** | **Source**

Contaminant		Aro C12-C16		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	3.20E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.00E+01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | **Variable**

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	2.41E+02	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	1.53E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.00E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

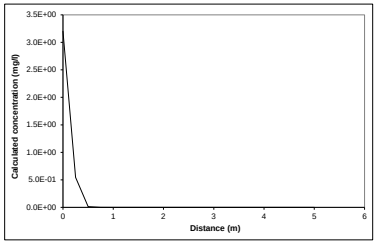
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}(x))^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	3.2E+00
0.3	5.46E-01
0.5	1.43E-02
0.8	4.68E-05
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Aro C16-C21			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aro C16-C21**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	6.95E-04	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment	**Kd**	**2.54E+02**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.27E+02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16-C21**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.31E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Aro C16-C21		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		16000	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.54E+02	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	6.78E+02	fraction
Decay rate used	λ	1.02E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.89E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	6.30E+01	mg/l

Remedial Targets

Level 3 Remedial Target	**No impact**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	No impact	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point	**5**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0 0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd [ ] l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.54E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

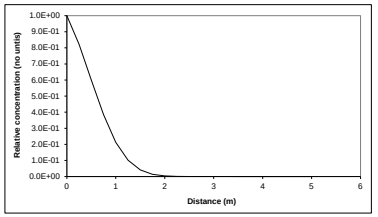
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	6.12E+01
0.3	8.20E-01	5.02E+01
0.5	6.00E-01	3.67E+01
0.8	3.84E-01	2.35E+01
1.0	2.13E-01	1.30E+01
1.3	1.02E-01	6.21E+00
1.5	4.12E-02	2.52E+00
1.8	1.42E-02	8.71E-01
2.0	4.16E-03	2.54E-01
2.3	1.02E-03	6.27E-02
2.5	2.13E-04	1.30E-02
2.8	3.71E-05	2.27E-03
3.0	3.01E-06	1.84E-04
3.3	3.68E-07	2.25E-05
3.5	3.77E-08	2.31E-06
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | Variable | Value | Unit | Source

Contaminant		Aro C16-C21		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	5.50E-01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.54E+02	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | Variable

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	6.78E+02	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	5.43E-07	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.54E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

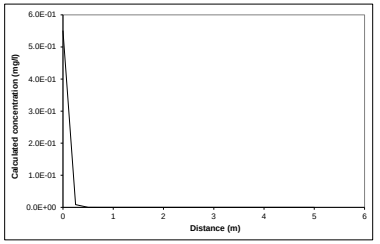
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**5.5E-01**
0.3	**8.46E-03**
0.5	**4.60E-07**
0.8	**0.00E+00**
1.0	**0.00E+00**
1.3	**0.00E+00**
1.5	**0.00E+00**
1.8	**0.00E+00**
2.0	**0.00E+00**
2.3	**0.00E+00**
2.5	**0.00E+00**
2.8	**0.00E+00**
3.0	**0.00E+00**
3.3	**0.00E+00**
3.5	**0.00E+00**
3.8	**0.00E+00**
4.0	**0.00E+00**
4.3	**0.00E+00**
4.5	**0.00E+00**
4.8	**0.00E+00**
5.0	**0.00E+00**

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Aro C21-C35			
Target Concentration (C_T)	0.5	mg/l	Origin of C_T:	Surface Waters Abstraction for Drinking Water Regs 19

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aro C21-C35**		
Target concentration	C_T	**0.5**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	2.48E-05	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	1.26E+05	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.26E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.13E+03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.5	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C21-C35**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	**C_T**	**0.5** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.16E+03	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Aro C21-C35		from Level 1
Target Concentration	C_T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		29000	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.26E+03	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	6.03E+03	fraction
Decay rate used	λ	1.15E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	2.12E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**>reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	1.28E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**No impact**	**mg/l**
Ogata Banks		**or**	
		No impact	**mg/kg**
Distance to compliance point		**5**	**m**
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**0.00E+00**	**fraction**

For comparison with measured pore water concentration.
This assumes Level 1 Remedial Target is based on Target Concentration.
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.26E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

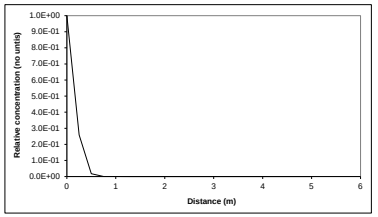
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.25E+01
0.3	2.59E-01	3.22E+00
0.5	1.79E-02	2.23E-01
0.8	2.86E-04	3.56E-03
1.0	9.86E-07	1.23E-05
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Aro C21-C35		from Level 1
Target Concentration	C_T	5.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.50E-01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.26E+03	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	6.03E+03	fraction
Decay rate used	λ	7.70E-101	d^{-1}
Rate of contaminant flow due to retardation	u	6.10E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.26E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

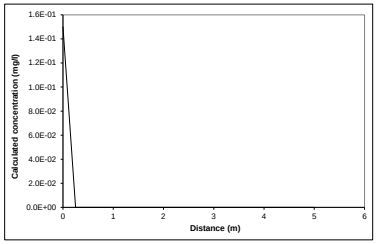
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.5E-01
0.3	0.00E+00
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Benzo(a)pyrene			
Target Concentration (C_T)	0.00027	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Benzo(a)pyrene**		
Target concentration	C_T	**0.00027**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.76E-06	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	
Organic carbon partition coefficient	Koc	1.29E+05	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.31E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**6.25E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.00027	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Benzo(a)pyrene**		from Level 1
Target concentration	C_T	**0.00027**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**2.78E-04**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		6.43E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Benzo(a)pyrene		from Level 1
Target Concentration	C_T	0.00027	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		1000	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.06E+03	days	*Mackay 2006*
Calculated decay rate	λ	6.51E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.31E+03	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	6.17E+03	fraction
Decay rate used	λ	1.06E-07	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	2.07E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**reakthrough at c**	**fraction**
Calculated soil leachate concentration	Co	4.32E-01	mg/l

Remedial Targets

Level 3 Remedial Target	No impact	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	No impact	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	5	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0** **0.00E+00**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.29E+05	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.31E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	4.20E-01
0.3	2.52E-01	1.06E-01
0.5	1.64E-02	6.89E-03
0.8	2.38E-04	1.00E-04
1.0	7.21E-07	3.02E-07
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu) | Variable | Value | Unit | Source

Contaminant		Benzo(a)pyrene		from Level 1
Target Concentration	C_T	2.70E-04	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.90E-03	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	1.06E+03	days	*Mackay 2006*
Calculated decay rate	λ	6.51E-04	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.31E+03	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters | Variable

Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	6.17E+03	fraction
Decay rate used	λ	1.06E-07	d^{-1}
Rate of contaminant flow due to retardation	u	5.96E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	1.29E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.31E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

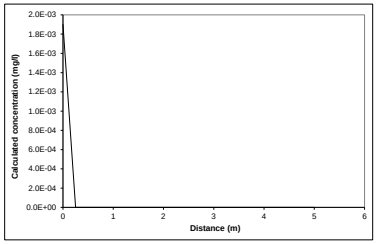
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.9E-03
0.3	0.00E+00
0.5	0.00E+00
0.8	0.00E+00
1.0	0.00E+00
1.3	0.00E+00
1.5	0.00E+00
1.8	0.00E+00
2.0	0.00E+00
2.3	0.00E+00
2.5	0.00E+00
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Benzene			
Target Concentration (C_T)	0.05	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Benzene**		
Target concentration	C_T	**0.05**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.16E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	6.76E+01	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.21E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**7.12E-02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.05	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Benzene**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.05** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**5.15E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		7.33E-02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Benzene		from Level 1
Target Concentration	C_T	0.05	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		200	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	7.20E+02	days	*Mackay 2006*
Calculated decay rate	λ	9.63E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.21E+00	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	4.24E+00	fraction
Decay rate used	λ	2.27E-04	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	3.02E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.95E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.44E+00**	**fraction**
Calculated soil leachate concentration	Co	1.40E+02	mg/l

Remedial Targets

Level 3 Remedial Target	**7.40E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.05E-01	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration (C_{ED}/C_0)	**6.95E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	6.76E+01	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.21E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

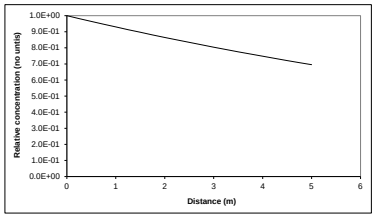
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.36E+02
0.3	9.82E-01	1.34E+02
0.5	9.64E-01	1.32E+02
0.8	9.47E-01	1.29E+02
1.0	9.30E-01	1.27E+02
1.3	9.13E-01	1.25E+02
1.5	8.97E-01	1.22E+02
1.8	8.81E-01	1.20E+02
2.0	8.65E-01	1.18E+02
2.3	8.49E-01	1.16E+02
2.5	8.34E-01	1.14E+02
2.8	8.19E-01	1.12E+02
3.0	8.04E-01	1.10E+02
3.3	7.90E-01	1.08E+02
3.5	7.75E-01	1.06E+02
3.8	7.62E-01	1.04E+02
4.0	7.48E-01	1.02E+02
4.3	7.34E-01	1.00E+02
4.5	7.21E-01	9.84E+01
4.8	7.08E-01	9.66E+01
5.0	6.95E-01	9.49E+01

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Benzene		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.60E+01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	7.20E+02	days	*Mackay 2006*
Calculated decay rate	λ	9.63E-04	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.21E+00	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	4.24E+00	fraction
Decay rate used	λ	2.27E-04	d^{-1}
Rate of contaminant flow due to retardation	u	8.68E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.83E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**8.74E+03**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	6.76E+01	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.21E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

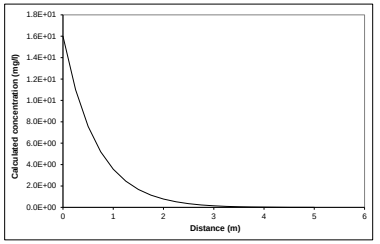
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.6E+01
0.3	1.10E+01
0.5	7.57E+00
0.8	5.20E+00
1.0	3.57E+00
1.3	2.45E+00
1.5	1.67E+00
1.8	1.14E+00
2.0	7.73E-01
2.3	5.21E-01
2.5	3.47E-01
2.8	2.29E-01
3.0	1.49E-01
3.3	8.80E-02
3.5	5.45E-02
3.8	3.30E-02
4.0	1.95E-02
4.3	1.13E-02
4.5	6.33E-03
4.8	3.46E-03
5.0	1.83E-03

Remedial Targets

Remedial Target		**4.37E+02**	**mg/l**
Ogata Banks			
Distance to compliance point		**5**	**m**
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**1.83E-03**	**mg/l**
after		**1.8E+04**	**days**

For comparison with measured groundwater concentration.

Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Carbazole			
Target Concentration (C_T)	0.0034	mg/l	Origin of C_T:	USEPA

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Carbazole**		
Target concentration	**C_T**	**0.0034**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.15E-03	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	7.76E+02	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.39E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.80E-02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0034	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Carbazole**		from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	**C_T**	**0.0034**	**mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**3.50E-03**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		4.95E-02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Carbazole		from Level 1
Target Concentration	C_T	0.0034	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		590	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.39E+01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	3.82E+01	fraction
Decay rate used	λ	1.82E-102	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	3.35E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	7.50E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.33E+00**	**fraction**
Calculated soil leachate concentration	Co	4.17E+01	mg/l

Remedial Targets

Level 3 Remedial Target	**4.67E-03**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	6.59E-02	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration C_{ED}/C_0	**7.50E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	7.76E+02	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.39E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

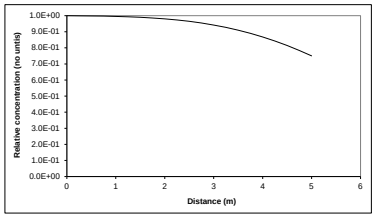
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	4.05E+01
0.3	9.99E-01	4.05E+01
0.5	9.99E-01	4.05E+01
0.8	9.97E-01	4.04E+01
1.0	9.96E-01	4.04E+01
1.3	9.93E-01	4.03E+01
1.5	9.90E-01	4.01E+01
1.8	9.86E-01	4.00E+01
2.0	9.80E-01	3.97E+01
2.3	9.73E-01	3.95E+01
2.5	9.65E-01	3.91E+01
2.8	9.54E-01	3.87E+01
3.0	9.42E-01	3.82E+01
3.3	9.27E-01	3.76E+01
3.5	9.10E-01	3.69E+01
3.8	8.90E-01	3.61E+01
4.0	8.68E-01	3.52E+01
4.3	8.42E-01	3.42E+01
4.5	8.14E-01	3.30E+01
4.8	7.84E-01	3.18E+01
5.0	7.50E-01	3.04E+01

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Carbazole		from Level 1
Target Concentration	C_T	3.40E-03	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	8.00E-03	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.90E+99	days	
Calculated decay rate	λ	7.00E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.39E+01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	3.82E+01	fraction
Decay rate used	λ	1.83E-102	d^{-1}
Rate of contaminant flow due to retardation	u	9.64E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	7.76E+02	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.39E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

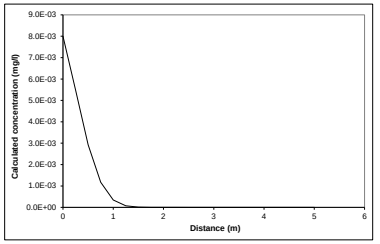
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	8.0E-03
0.3	5.48E-03
0.5	2.92E-03
0.8	1.17E-03
1.0	3.47E-04
1.3	7.46E-05
1.5	1.15E-05
1.8	1.28E-06
2.0	1.01E-07
2.3	3.03E-09
2.5	1.20E-10
2.8	0.00E+00
3.0	0.00E+00
3.3	0.00E+00
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Naphthalene			
Target Concentration (C_T)	0.13	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Naphthalene**		
Target concentration	**C_T**	**0.13**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	6.62E-03	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	Soil sample analysis
Organic carbon partition coefficient	Koc	6.46E+02	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.16E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.53E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.13	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Naphthalene**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	**C_T**	**0.13** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**1.34E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.58E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	0.13	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		9100	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.58E+02	days	*Mackay 2006*
Calculated decay rate	λ	2.69E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.16E+01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	3.19E+01	fraction
Decay rate used	λ	8.41E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	4.00E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	3.62E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**2.76E+00**	**fraction**
Calculated soil leachate concentration	Co	7.72E+02	mg/l

Remedial Targets

Level 3 Remedial Target	**3.70E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	4.36E+00	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration (C_{ED}/C_0)	**3.62E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	6.46E+02	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.16E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

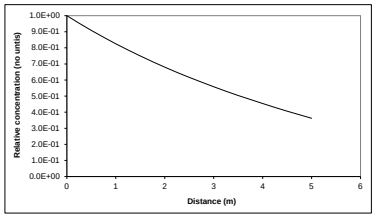
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	7.50E+02
0.3	9.53E-01	7.15E+02
0.5	9.08E-01	6.81E+02
0.8	8.66E-01	6.49E+02
1.0	8.25E-01	6.19E+02
1.3	7.86E-01	5.90E+02
1.5	7.49E-01	5.62E+02
1.8	7.14E-01	5.35E+02
2.0	6.80E-01	5.10E+02
2.3	6.48E-01	4.86E+02
2.5	6.17E-01	4.62E+02
2.8	5.87E-01	4.40E+02
3.0	5.58E-01	4.18E+02
3.3	5.31E-01	3.98E+02
3.5	5.04E-01	3.78E+02
3.8	4.79E-01	3.59E+02
4.0	4.54E-01	3.40E+02
4.3	4.30E-01	3.22E+02
4.5	4.07E-01	3.05E+02
4.8	3.84E-01	2.88E+02
5.0	3.62E-01	2.72E+02

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	1.30E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.00E+01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	2.58E+02	days	*Mackay 2006*
Calculated decay rate	λ	2.69E-03	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.16E+01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	3.19E+01	fraction
Decay rate used	λ	8.41E-05	d^{-1}
Rate of contaminant flow due to retardation	u	1.15E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	6.46E+02	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.16E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

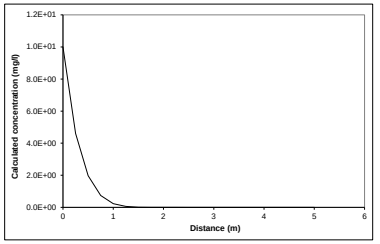
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E+01
0.3	4.61E+00
0.5	1.97E+00
0.8	7.40E-01
1.0	2.33E-01
1.3	5.90E-02
1.5	1.18E-02
1.8	1.82E-03
2.0	1.48E-04
2.3	1.29E-05
2.5	8.56E-07
2.8	4.28E-08
3.0	1.61E-09
3.3	4.56E-11
3.5	0.00E+00
3.8	0.00E+00
4.0	0.00E+00
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Phenol			
Target Concentration (C_T)	0.0077	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Phenol**		
Target concentration	C_T	**0.0077**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	8.35E-06	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	
Organic carbon partition coefficient	Koc	2.88E+01	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.18E-01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.43E-03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0077	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Phenol**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.0077** **mg/l**	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**7.93E-03**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		5.59E-03	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Phenol		from Level 1
Target Concentration	C_T	0.0077	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		2500	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	7.00E+00	days	*Mackay 2006*
Calculated decay rate	λ	9.90E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.18E-01	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	2.38E+00	fraction
Decay rate used	λ	4.16E-02	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	5.37E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.26E-07	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**4.43E+06**	**fraction**
Calculated soil leachate concentration	Co	3.54E+03	mg/l

Remedial Targets

Level 3 Remedial Target	**3.51E+04**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.48E+04	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point	**5**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration (C_{ED}/C_0)	**2.26E-07**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.88E+01	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.18E-01	l/kg

Define dispersivity (click brown cell and use pull down list)

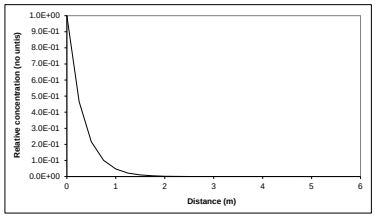
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	3.44E+03
0.3	4.65E-01	1.60E+03
0.5	2.16E-01	7.45E+02
0.8	1.01E-01	3.47E+02
1.0	4.69E-02	1.61E+02
1.3	2.18E-02	7.50E+01
1.5	1.01E-02	3.49E+01
1.8	4.72E-03	1.62E+01
2.0	2.20E-03	7.56E+00
2.3	1.02E-03	3.52E+00
2.5	4.75E-04	1.64E+00
2.8	2.21E-04	7.61E-01
3.0	1.03E-04	3.54E-01
3.3	4.79E-05	1.65E-01
3.5	2.23E-05	7.66E-02
3.8	1.04E-05	3.57E-02
4.0	4.82E-06	1.66E-02
4.3	2.24E-06	7.72E-03
4.5	1.04E-06	3.59E-03
4.8	4.86E-07	1.67E-03
5.0	2.26E-07	7.77E-04

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Phenol		from Level 1
Target Concentration	C_T	7.70E-03	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	9.35E+01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	7.00E+00	days	*Mackay 2006*
Calculated decay rate	λ	9.90E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.18E-01	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	2.38E+00	fraction
Decay rate used	λ	4.16E-02	d^{-1}
Rate of contaminant flow due to retardation	u	1.55E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	5.25E-47	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.78E+48**	

Remedial Targets

Remedial Target		**1.37E+46**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**5.25E-47**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.88E+01	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.18E-01	l/kg

Define dispersivity (click brown cell and use pull down list)

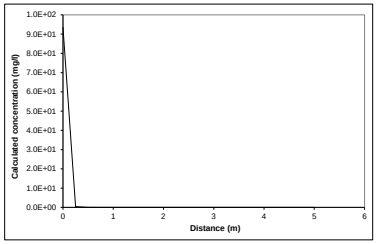
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	9.4E+01
0.3	3.62E-01
0.5	1.40E-03
0.8	5.41E-06
1.0	2.09E-08
1.3	8.09E-11
1.5	3.13E-13
1.8	1.21E-15
2.0	4.68E-18
2.3	1.81E-20
2.5	7.01E-23
2.8	2.71E-25
3.0	1.05E-27
3.3	4.05E-30
3.5	1.57E-32
3.8	6.07E-35
4.0	2.35E-37
4.3	9.07E-40
4.5	3.51E-42
4.8	1.36E-44
5.0	5.25E-47

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Toluene			
Target Concentration (C_T)	0.074	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Toluene**		
Target concentration	C_T	**0.074**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.15E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	
Organic carbon partition coefficient	Koc	2.04E+02	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**3.67E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.87E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.074	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Toluene**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.074** mg/l	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**7.62E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.95E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Toluene		from Level 1
Target Concentration	C_T	0.074	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		310	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.20E+01	days	*Mackay 2006*
Calculated decay rate	λ	3.15E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.67E+00	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	1.08E+01	fraction
Decay rate used	λ	2.92E-03	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	7.66E-04	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.30E+03**	**fraction**
Calculated soil leachate concentration	Co	8.00E+01	mg/l

Remedial Targets

Level 3 Remedial Target	**9.94E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	3.85E+02	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration C_{ED}/C_0	**7.66E-04**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.04E+02	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	3.67E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

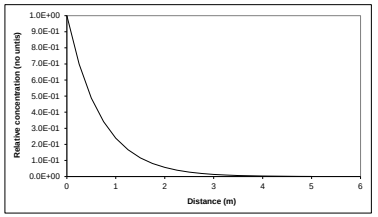
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	7.77E+01
0.3	6.99E-01	5.43E+01
0.5	4.88E-01	3.79E+01
0.8	3.41E-01	2.65E+01
1.0	2.38E-01	1.85E+01
1.3	1.66E-01	1.29E+01
1.5	1.16E-01	9.03E+00
1.8	8.12E-02	6.31E+00
2.0	5.67E-02	4.41E+00
2.3	3.96E-02	3.08E+00
2.5	2.77E-02	2.15E+00
2.8	1.93E-02	1.50E+00
3.0	1.35E-02	1.05E+00
3.3	9.44E-03	7.33E-01
3.5	6.59E-03	5.12E-01
3.8	4.61E-03	3.58E-01
4.0	3.22E-03	2.50E-01
4.3	2.25E-03	1.75E-01
4.5	1.57E-03	1.22E-01
4.8	1.10E-03	8.52E-02
5.0	7.66E-04	5.95E-02

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Toluene		from Level 1
Target Concentration	C_T	7.40E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.80E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	2.20E+01	days	*Mackay 2006*
Calculated decay rate	λ	3.15E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.67E+00	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	1.08E+01	fraction
Decay rate used	λ	2.92E-03	d^{-1}
Rate of contaminant flow due to retardation	u	3.41E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.26E-26	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**2.12E+26**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	2.04E+02	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	3.67E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

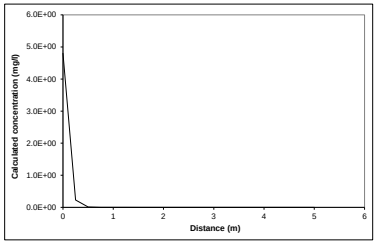
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	4.8E+00
0.3	2.32E-01
0.5	1.12E-02
0.8	5.40E-04
1.0	2.61E-05
1.3	1.26E-06
1.5	6.07E-08
1.8	2.93E-09
2.0	1.41E-10
2.3	6.83E-12
2.5	3.29E-13
2.8	1.59E-14
3.0	7.68E-16
3.3	3.70E-17
3.5	1.79E-18
3.8	8.63E-20
4.0	4.17E-21
4.3	2.01E-22
4.5	9.71E-24
4.8	4.69E-25
5.0	2.26E-26

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Remedial Targets

Remedial Target		**1.57E+25**	**mg/l**
Ogata Banks			
Distance to compliance point		**5**	**m**
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**2.26E-26**	**mg/l**
after		**1.8E+04**	**days**

For comparison with measured groundwater concentration.

Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Xylene			
Target Concentration (C_T)	0.3	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Xylene**		
Target concentration	C_T	**0.3**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	1.07E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.80E-02	fraction	
Organic carbon partition coefficient	Koc	4.47E+02	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**8.02E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.47E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.3	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Xylene**	from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	C_T	**0.3** mg/l	from Level 1	

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**3.09E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.54E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Xylene		from Level 1
Target Concentration	C_T	0.3	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		11900	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	3.60E+02	days	*Mackay 2006*
Calculated decay rate	λ	1.93E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	8.02E+00	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	2.24E+01	fraction
Decay rate used	λ	8.60E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	5.71E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	4.90E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**2.04E+00**	**fraction**
Calculated soil leachate concentration	Co	1.45E+03	mg/l

Remedial Targets

Level 3 Remedial Target	**6.30E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	5.18E+00	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**5**	**m**	
Ratio of Compliance Point to Source Concentration C_{ED}/C_0	**4.90E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	4.47E+02	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	8.02E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

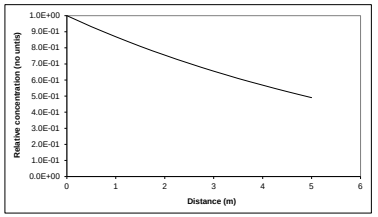
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.40E+03
0.3	9.65E-01	1.36E+03
0.5	9.32E-01	1.31E+03
0.8	9.00E-01	1.26E+03
1.0	8.69E-01	1.22E+03
1.3	8.39E-01	1.18E+03
1.5	8.10E-01	1.14E+03
1.8	7.82E-01	1.10E+03
2.0	7.55E-01	1.06E+03
2.3	7.28E-01	1.02E+03
2.5	7.03E-01	9.87E+02
2.8	6.79E-01	9.53E+02
3.0	6.55E-01	9.20E+02
3.3	6.32E-01	8.87E+02
3.5	6.10E-01	8.56E+02
3.8	5.89E-01	8.26E+02
4.0	5.68E-01	7.97E+02
4.3	5.48E-01	7.69E+02
4.5	5.28E-01	7.41E+02
4.8	5.09E-01	7.15E+02
5.0	4.90E-01	6.89E+02

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Xylene		from Level 1
Target Concentration	C_T	3.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.80E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	3.60E+02	days	*Mackay 2006*
Calculated decay rate	λ	1.93E-03	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	8.02E+00	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	2.24E+01	fraction
Decay rate used	λ	8.60E-05	d^{-1}
Rate of contaminant flow due to retardation	u	1.64E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.80E-02	fraction
Organic carbon partition coefficient	Koc	4.47E+02	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	8.02E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

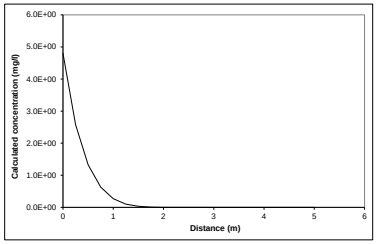
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	4.8E+00
0.3	2.58E+00
0.5	1.33E+00
0.8	6.32E-01
1.0	2.71E-01
1.3	1.02E-01
1.5	3.27E-02
1.8	8.91E-03
2.0	2.03E-03
2.3	2.70E-04
2.5	4.13E-05
2.8	5.21E-06
3.0	5.41E-07
3.3	4.61E-08
3.5	3.23E-09
3.8	1.84E-10
4.0	8.63E-12
4.3	0.00E+00
4.5	0.00E+00
4.8	0.00E+00
5.0	0.00E+00

Remedial Targets

Remedial Target		No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment				
Site Name:	Glassworks, Phase 2			
Site Address:	Barnsley Town Centre			
Completed by:	M Kelly			
Date:	10-Dec-18		Version:	0.1
Contaminant	Zinc			
Target Concentration (C_T)	0.0109	mg/l	Origin of C_T:	EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Zinc**		
Target concentration	C_T	**0.0109**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.00E-01	fraction	SR3 default for clay.
Air filled soil porosity	θa	3.00E-01	fraction	SR3 default for clay.
Bulk density of soil zone material	ρ	1.60E+00	g/cm^3	SR3 default for clay.
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	2.60E+03	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.60E+03**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.83E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0109	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Zinc**		from Level 1
Target concentration	C_T	**0.0109**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	9.50E-04	m/d	**Based on long term rainfall averages.**	
Area of contaminant source	A	1.20E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	4.00E+01	m	**Based on site investigation data.**	
Saturated aquifer thickness	da	5.10E+00	m	**Estimate based on thickness of made ground.**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	9.20E-03	m/d	**Site specific value from test data.**	
Hydraulic gradient of water table	i	2.40E-02	fraction	**Based on site groundwater levels.**	
Width of contaminant source perpendicular to groundwater flow	w	3.00E+01	m	**Based on site investigation data.**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	5.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.03E+00**		
Level 2 Remedial Target		**1.12E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.92E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	10-Dec-18
Version:	0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Zinc		from Level 1
Target Concentration	C_T	0.0109	mg/l	from Level 1
Dilution Factor	DF	1.03E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		250	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	9.90E+99	days	
Calculated decay rate	λ	7.00E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	3.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	5.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 Default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim values for clay*
Hydraulic gradient	i	8.34E-01	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	9.20E-03	m/d	from Level 2
Distance to compliance point	x	5.00E+00	m	*Approximate distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.60E+03	l/kg	*see options*
Longitudinal dispersivity	ax	0.500	m	*see options*
Transverse dispersivity	az	0.050	m	*see options*
Vertical dispersivity	ay	0.005	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.28E-02	m/d
Retardation factor	Rf	6.93E+03	fraction
Decay rate used	λ	1.01E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	8.34E-01	fraction
Rate of contaminant flow due to retardation	u	1.84E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction
Attenuation factor (C_0/C_{ED})	AF	reakthrough at c	fraction
Calculated soil leachate concentration	Co	9.61E-02	mg/l

Remedial Targets

Level 3 Remedial Target		No impact	mg/l	For comparison with measured pore water concentration.
Ogata Banks		or		This assumes Level 1 Remedial Target is based on Target Concentration.
		No impact	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point		5	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	0.00E+00	fraction	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — 2.60E+03 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer — foc — fraction
Organic carbon partition coefficient — Koc — l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species — $K_{oc,n}$ — l/kg
Sorption coefficient for ionised species — $K_{oc,i}$ — l/kg
pH value — pH
Acid dissociation constant — pKa
Fraction of organic carbon in aquifer — foc — fraction

Soil water partition coefficient — Kd — 2.60E+03 — l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	az	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	ay	0.00E+00	5.00E-03	3.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	9.34E-02
0.3	2.20E-01	2.05E-02
0.5	1.04E-02	9.74E-04
0.8	9.05E-05	8.45E-06
1.0	1.34E-07	1.25E-08
1.3	0.00E+00	0.00E+00
1.5	0.00E+00	0.00E+00
1.8	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00
2.3	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00
3.3	0.00E+00	0.00E+00
3.5	0.00E+00	0.00E+00
3.8	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00
4.3	0.00E+00	0.00E+00
4.5	0.00E+00	0.00E+00
4.8	0.00E+00	0.00E+00
5.0	0.00E+00	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Zinc		from Level 1
Target Concentration	C_T	1.09E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	9.35E+01	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	9.90E+99	days	
Calculated decay rate	λ	7.00E-101	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	3.00E+01	m	*Based on site investigation data*
Plume thickness at source	Sy	5.10E+00	m	*Aquifer thickness*
Saturated aquifer thickness	da	5.10E+00	m	*Aquifer thickness*
Bulk density of aquifer materials	ρ	1.60E+00	g/cm^3	*SR3 default for clay*
Effective porosity of aquifer	n	6.00E-01	fraction	*Based on Consim value for clay*
Hydraulic gradient	i	2.40E-02	fraction	*Based on site measurements*
Hydraulic conductivity of aquifer	K	9.20E-03	m/d	*Based on site measurements*
Distance to compliance point	x	5.00E+00	m	*Distance to Sough Dyke*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.83E+04	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.60E+03	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E-01	m	*see options*
Transverse dispersivity	az	5.00E-02	m	*see options*
Vertical dispersivity	ay	5.00E-03	m	*see options*

Dispersed plume thickness exceeds aquifer thickness! Reduce vertical dispersivity

Calculated Parameters

	Variable		
Groundwater flow velocity	v	3.68E-04	m/d
Retardation factor	Rf	6.93E+03	fraction
Decay rate used	λ	1.01E-104	d^{-1}
Rate of contaminant flow due to retardation	u	5.31E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**breakthrough at compliance point**	

Remedial Targets

Remedial Target		**No impact**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**5**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**0.00E+00**	**mg/l**	Ogata Banks
after		**1.8E+04**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	2.60E+03	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.60E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

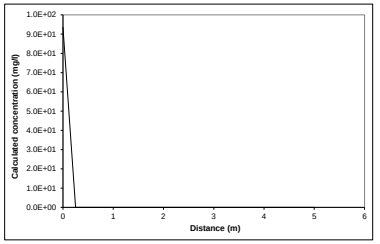
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	5.00E-01	3.50E-01	m
Transverse dispersivity	**az**	0.00E+00	5.00E-02	3.50E-02	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-03	3.50E-03	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Glassworks, Phase 2
Completed by:	M Kelly
Date:	########
Version:	0.1

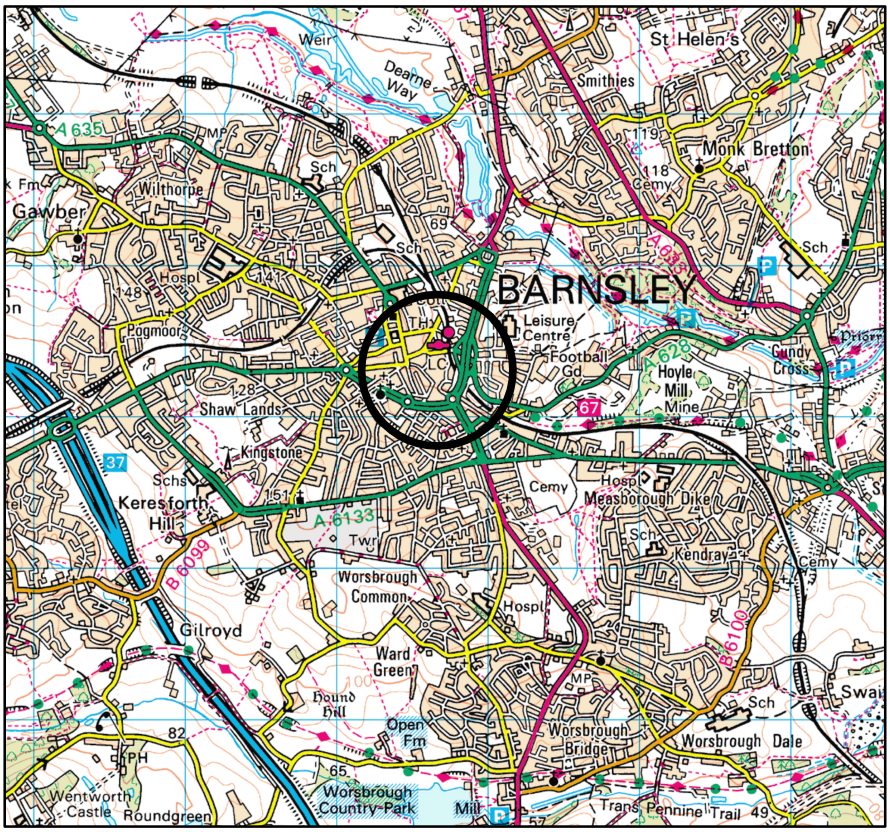
Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**9.4E+01**
0.3	**0.00E+00**
0.5	**0.00E+00**
0.8	**0.00E+00**
1.0	**0.00E+00**
1.3	**0.00E+00**
1.5	**0.00E+00**
1.8	**0.00E+00**
2.0	**0.00E+00**
2.3	**0.00E+00**
2.5	**0.00E+00**
2.8	**0.00E+00**
3.0	**0.00E+00**
3.3	**0.00E+00**
3.5	**0.00E+00**
3.8	**0.00E+00**
4.0	**0.00E+00**
4.3	**0.00E+00**
4.5	**0.00E+00**
4.8	**0.00E+00**
5.0	**0.00E+00**

D R A W I N G S

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CLIENT: HENRY BOOT CONSTRUCTION	DRG No.: SH12158-001		REV: A
	SIZE: A4	SCALE: 1:50000	DATE: 28/09/18
PROJECT: GLASSWORKS PHASE 2, BARNSLEY	DRAWN BY: DP	CHECKED BY: AD	APPROVED BY: AD
DRAWING TITLE: SITE LOCATION PLAN			

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REFERENCE

SITE BOUNDARY

ALIGNMENT OF SOUGH DYKE TAKEN FROM CHARTER OAKS TOPOGRAPHICAL SURVEY MARCH 2007

PRELIMINARY STAGE 1 SITE INVESTIGATION LOCATIONS (2007)

(SHALLOW) BOREHOLE LOCATIONS BH101

(DEEP) BOREHOLE LOCATIONS BH102

WINDOW SAMPLING LOCATIONS WS103

STAGE 2 SITE INVESTIGATION LOCATIONS

ROTARY CORE DRILLING (WITH PRESSUREMETER TESTS) COMMENCED BY CABLE PERCUSSION WHERE APPROPRIATE BH212

ROTARY CORE DRILLING COMMENCED BY CABLE PERCUSSION WHERE APPROPRIATE BH203

ROTARY OPEN-HOLE DRILLING COMMENCED BY CABLE PERCUSSION WHERE APPROPRIATE BH220

CABLE PERCUSSION BH204

WINDOW SAMPLING WS237

TRIAL PIT EXCAVATION TP271

SOIL ENGINEERING 2017 BH02 WS06 TP03

SURFACE WATER POINT SW1

NOTES:

1. SURFACE SURVEY BASED ON DWG. No. 030701-01 SHEETS 1 TO 4 ; TOPOGRAPHICAL SURVEY, GROUND LEVEL BARNSLEY MARKETS BY CHARTER OAKS LTD ON BEHALF OF CZWG ARCHITECTS DATED MARCH 2007.
2. BASEMENT SURVEY SHOWN IN BLUE. BASED ON DWG. No. 030701-06 BY CHARTER OAKS LTD. ON BEHALF OF CZWG ARCHITECTS DATED MARCH 2007. ALL BOREHOLES WITHIN THE CONFINES OF THE BASEMENT SURVEY ARE AT BASEMENT LEVEL.
3. SOUGH DYKE ALIGNMENT TAKEN FROM CHARTER OAKS TOPOGRAPHICAL SURVEY DRG No 030701-01 MARCH 2002
4. PRELIMINARY STAGE 1 (2007) BOREHOLE LOCATIONS AND LEVELS BASED UPON SURVEY CONDUCTED BY WARDELL ARMSTRONG DATED SEPT. 2007.
5. STAGE 2 (2008) BOREHOLE LOCATIONS AND LEVELS BASED UPON SURVEY CONDUCTED BY WARDELL ARMSTRONG DATED APRIL 2008.

REVISION	DETAILS	DATE	DRAWN	CHK'D	APP'D
A	First Issue	09/01/19	DP	AD	AD

CLIENT: HENRY BOOT CONSTRUCTION

PROJECT: GLASSWORKS PHASE 2, BARNSLEY

DRAWING TITLE: SITE INVESTIGATION PLAN

DRG No.	REV
SH12158-003	

DRG SIZE	SCALE	DATE
A1	1:500	18/12/18

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