

Fact sheet for the RBCA Tool Kit for Chemical Releases

Basic model information

- Model name:** Risk-Based Corrective Action (RBCA) Tool Kit for Chemical Releases (Version 1.3)
- Available from:** Groundwater Services, Inc., 2211 Norfolk, Suite 1000, Houston, Texas 77098-4044, USA
www.gsi-net.com
- Cost:** \$795 (USA)
- Developed by:** RBCA Framework (American Society for Testing and Materials)
RBCA Tool Kit
(Groundwater Services Inc., USA)
- Hardware:** Minimum of 32 MB RAM and 25 MB free disk space
Microsoft Excel v7.0 or Excel 97

Brief model description

The RBCA Tool Kit for Chemical Releases consists of a series of linked workbooks programmed in Microsoft® Excel version 7.0 or 97 [1]. This tool can be used to calculate risk levels (i.e. 1 in a million) and/or "cleanup standards"¹ for soil and groundwater (e.g. 10 mg/kg for soil or 10 mg/L for groundwater). These values are calculated based on information provided by the user. The RBCA Tool Kit is designed to be protective of human health and the environment.

The Tool Kit was specifically designed to complete all calculations required for Tier 1 and Tier 2 of the RBCA planning process, as defined in the ASTM (American Society for Testing and Material) E2081-00 Standard Guide for Risk-Based Corrective Action [2]. This includes the calculation of exposure concentrations and average daily intake of contaminants by humans.

The Tool Kit includes analytical fate and transport models for air, groundwater and soil exposure pathways. The user can enter suitable site-specific soil, groundwater and air parameters.

¹ It must be emphasised that "cleanup standards" may not be the same as remedial objectives or remedial standards within the context of UK regulation



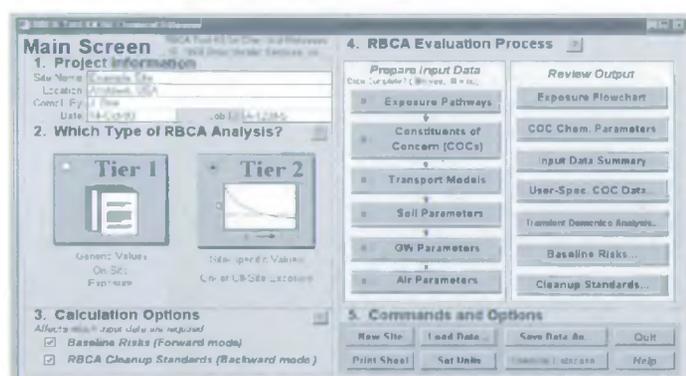
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The user selects the level of assessment required as follows:

- Tier 1 assessment involves the generation of generic risk-based screening level (RBSL) for on-site exposure only, assuming default exposure and site parameters
- Tier 2 allows the user to evaluate risk levels and/or site-specific target levels (SSTLs) for both on-site and off-site receptor locations based on site-specific soil, groundwater and air parameters. In a Tier 2 assessment the user may implement the fate and transport models included in the Tool Kit to evaluate off-site receptors

Figure 1 provides an example of the RBCA Tool Kit main screen and illustrates the options presented in the Tool Kit Main Screen.

Figure 1 RBCA Tool Kit main screen
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The forward mode option is used to calculate risk levels, based on measured concentrations of the contaminant of concern in soils and groundwater. The back-calculating mode of the programme can be utilised to back-calculate "cleanup standards". This tool was specifically designed for use in the USA based within the US regulatory context. However, the default parameters can be modified to evaluate sites within the UK.

Contaminants and contaminated media

An integrated toxicological and physico-chemical parameter database of 115 chemicals is provided in the Tool Kit. These include metals and organic parameters, and also, aliphatic and aromatic carbon chain lengths specified in the TPH Criteria Working Group (TPHCWG) methodology.

The Tool Kit can evaluate surface soil, subsurface soil, air, groundwater and surface water. However, contaminant concentrations can only be specified for soil and groundwater.

Lead is not included in the database. The user can customise the database to alter the parameters or add new chemicals.

Receptor types

Both on-site and off-site receptors can be considered. In RBCA on-site refers to a receptor directly above the source area, and off-site to a receptor at any point away from the source area (i.e. not related to the site boundary, see Figure 3). The receptor types included in the model are:

- groundwater
- surface water
- adult residential
- child residential
- adult commercial
- construction worker

Land-use and exposure scenarios

There is no default land-use scenario in the RBCA Tool Kit. The user has to select the receptor type, which can be either a residential receptor or a commercial / construction worker. The following exposure pathways and scenarios are included in the software:

Groundwater/surface water exposure:

- ingestion of groundwater
- inhalation of groundwater vapour
- discharge of contaminated groundwater to surface water
- ingestion/dermal contact via swimming
- ingestion via fish consumption
- aquatic life protection

Surface soil exposure (0 to <1 m):

- inhalation of vapour and particulates
- direct dermal contact
- ingestion of soil and dust (incidental)
- leaching to groundwater

Subsurface soil exposure (>1 m):

- inhalation of vapours
- leaching to groundwater

Air exposures are all included in the media specific exposures listed above.

The RBCA Tool Kit does not include the consumption of garden vegetables, dairy products, eggs, meat, fish or shellfish.

Key features of the model

What the model is supposed to do (model utility)

The RBCA Tool Kit was developed for use in the USA, taking into consideration the US regulatory context. Therefore, if it is used for sites in the UK it needs to be applied by considering the UK regulatory context. The RBCA Tool Kit can be used to derive generic and site-specific target levels that can be used to support risk management actions. The model can be used to simulate fate and transport of contaminants both on-site and off-site. The RBCA Tool Kit for Chemical Releases is a deterministic model (i.e. it uses a single value for each exposure parameter).

The default target risk levels are those for a residential land use. If another land use is evaluated, then the target risk input parameters must be altered to reflect this change.

Although the Tool Kit is a deterministic model, simple statistics may be applied to source area concentration data to calculate a representative value. The available statistical options are:

- maximum values
- arithmetic and/or geometric means
- confidence levels (e.g. 95% confidence levels)

The user must also note that the model assumes a constant source with no declining source options (i.e. the source concentration will never decrease during the assessment period).

Model usability

The RBCA Tool Kit has a good user interface, and can be described as user friendly. However, it must be noted that it is a complex model; for it to be used appropriately and effectively, considerable technical skill in risk assessment is required.

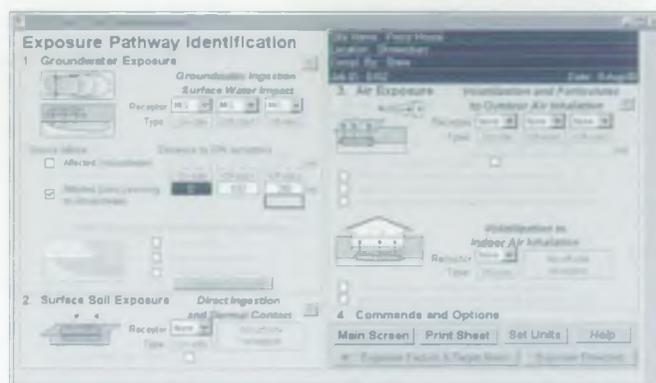
The operation of the programme is within Excel and data is entered onto Excel spreadsheets. There is a Main Screen that displays the risk assessment process (see Figure 1). The Main Screen is automatically displayed whenever the RBCA Tool Kit is opened, and it serves as the hub of the user interface. Most of the input and output screens are accessed from and returned to this screen. Here the user enters or selects:

- general project information (e.g. site name, site location)
- the type of RBCA analysis (e.g. Tier 1 or 2)
- calculations to be performed (e.g. calculation of risk values or "cleanup standards")

The user then progresses through the RBCA evaluation process by navigating to the appropriate input and output screens (e.g. Figure 2). Input and output

options become successively available as individual steps of the process are completed. In addition, the user may create, load and save user-input data files.

Figure 2 Exposure Pathway Identification screen
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There are also help files within each screen that can help the user identify what information is required. Although the help files do not contain the equations, the manual does include the full equations for many of the fate and transport modelling methods used in the spreadsheets. In addition, there is a unit conversion feature that can be used if the available data needs to be input with different units.

Finally, it is important to note that in order for this tool to be used appropriately, it must be used in conjunction with the manual and the ASTM standards [1 and 2].

Toxicological information

The software contains a database of 115 chemicals. The user can alter the default toxicological and physico-chemical information within the database. Any alteration from the default values is highlighted in the output. The toxicological information found in the database has been compiled from several sources including the USEPA Integrated Risk Information System (IRIS) and the USEPA Health Effects Assessment Summary Tables (HEAST). The toxicological parameters listed in these databases are classified as carcinogens and non-carcinogens, and therefore the derivation and resulting units are different. Reference doses (RfD) and slope factors are the toxicological entities used when evaluating non-carcinogens and carcinogens respectively. Table 1 contains examples of three contaminants and their associated carcinogenic and non-carcinogenic toxicological values.

Table 1 Example of toxicological information in the Tool Kit

Contaminant	RfD (mg/kg/day)	Slope factors (mg/kg/day) ¹
Arsenic	3.0 E-04	1.5
Trichloroethene	6.0 E-03	1.1 E-02
Benzo (a) Pyrene	NA	7.3

The user must ensure that any toxicological information used in the risk assessment complies with the UK regulatory context [3]. It is worth noting that the RBCA Tox database was compiled when the software was written and is not regularly updated. DEFRA and the Environment Agency have produced a number of contaminant toxicological reports [4], and the data within these should be used when conducting risk assessments within the UK.

Contaminants and contact media

Clicking "Constituents of Concern (COCs)" on the Main Screen accesses the Contaminant Selection screen. During this step the user must identify the constituents of concern (COCs) present at the site. Identified concentrations for COCs do not need to be input if "cleanup levels" (i.e. RBSLs or SSTLs) are only required. However, if risk levels are to be calculated, the user must also provide representative concentrations of the COCs in the relevant media. If only "cleanup levels" are required and the user includes representative site contaminant levels then the programme will highlight the exceeded "cleanup levels" automatically.

For Tier 1 evaluations using RBCA, any constituent associated with the source and consistently detected above natural background levels can be considered a possible COC. Only those constituents present above Tier 1 RBSLs are typically considered as COCs for a Tier 2 assessment.

The user must input the COC concentrations into the soil and groundwater columns, if these media have been identified as affected during the exposure pathway selection stage (Forward mode only). If this is not done then the user cannot continue into the next step of the assessment.

The Tool Kit can assess free product contamination through the use of Raoult's Law. The programme assesses the transport of dissolved phase but not free product.

Receptor characterisation

The human receptors evaluated in this software are:

- adult residential
- child residential
- commercial
- construction worker

The averaging time used for carcinogens and for all receptors is 70 years. The default averaging time for non-carcinogens and for the identified receptors are:

- 30 years for the adult residential receptor
- 25 years for the commercial receptor
- 1 year for the construction worker

The child receptor is evaluated into 0 to 6 or 0 to 16 age classes.

Table 2 Reasonable maximum exposure parameters

Parameter	Adult	Child (0-6)	Child (0-16)	Commercial	Construction
Body weight (kg)	70	15	35	70	70
Exposure duration (yr)	30	6	16	25	1
Exposure frequency (d/yr)	350	350	350	250	180
Dermal exposure frequency (d/yr)	350	350	350	250	250
Skin surface area (cm ²)	5,800		2,023	5,800	5,800
Water ingestion rate (L/d)	2	2	2	1	1
Soil ingestion rate (mg/d)	100	200	-	50	100
Swimming exposure time (hr/event)	3	3	3	NA	NA
Swimming exposure frequency (event/yr)	12	12	12	NA	NA
Swimming water ingestion rate (L/hr)	0.05	0.5	-	NA	NA
Skin surface area, swimming (cm ²)	23,000	-	8,100	NA	NA
Fish consumption rate (kg/d)	0.025	0.025	0.025	NA	NA

Table 2 contains the other default exposure parameters used in the assessment for each receptor. These parameters are all based on the reasonable maximum exposure (RME) concept, where the highest exposure that is reasonably expected to occur at a site is used.

These parameters are based on conservative US statistics. Therefore, when using this model these parameters need to be considered within the UK context.

Land use

There is no explicit land use in the software. However, from the description of the receptors the user can see that the land use can be identified as:

- residential (adult and child)
- recreational (adult and child)
- commercial/construction.

Pathway characterisation

During the Tier 1 assessment only on-site exposure pathways for both human health and groundwater can be evaluated. Therefore, all other receptors and off-site exposure pathways are greyed out so that the user cannot select them. These only become available if the Tier 2 assessment is conducted.

The exposure and migration pathways that can be evaluated during a Tier 1 assessment for the on-site receptors are:

- groundwater ingestion (on-site)
 - commercial
 - residential
 - maximum contaminant levels (MCLs)
- surface soil (direct ingestion and dermal contact on-site)
 - residential
 - commercial
 - construction worker
- air (volatilisation and particulates to outdoor air and volatilisation to indoor air, on-site)
 - residential
 - commercial
 - construction worker (no indoor air volatilisation)
 - time-weighted average (TWA)

The MCLs listed in the software are a drinking water standard established by USEPA under the Safe Drinking Water Act. They are the maximum permissible levels of chemicals of concern in water that is to be delivered to any user of a public water supply. These values are different from the UK drinking water standards, and the user should ensure that the appropriate values are entered if necessary.

The construction worker pathway can only be evaluated if either the residential or commercial receptors have been selected first. Therefore, this receptor cannot be evaluated separately. Additionally, the US Occupational Safety and Health Administration (OSHA) have published permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. These limits are based on an 8 hour time weighted average (TWA) exposure. Should this option be used in the UK, then the values published by the Health and Safety Executive (HSE) in EH40 [5] should be used instead of the OSHA PELs.

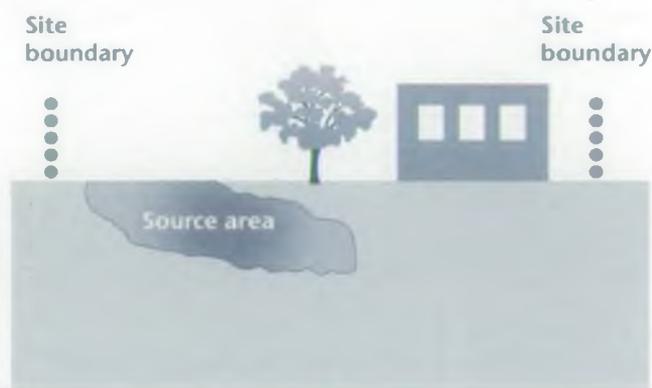
It is also important to note that the term 'on-site receptor' refers to an on-source receptor (i.e. a receptor immediately on the source area). Figure 3 illustrates this concept. The off-site receptor does not

necessarily need to be outside the site boundary, nor does the on-site receptor need to be located inside the boundary. In this figure the receptors are represented by the house/building structure.

Figure 3a | Example of an on-site receptor



Figure 3b | Example of an off-site receptor



In addition to the exposure pathways listed above for the on-site receptor, the following exposure pathways can be selected for the off-site receptors during a Tier 2 assessment:

- groundwater (a maximum of two off-site receptors can be selected in which surface water may be one)
 - residential
 - commercial
 - MCLs
 - surface water impacts
 - surface water (ingestion of fish)
- air (two off-site receptors can be selected)
 - residential
 - commercial
 - TWA.

Model outputs

One of the most important outputs from the model is the input summary sheet. This sheet contains all the exposure parameters and migration models selected. It is extremely important that this sheet accompanies any risk assessment conducted with this model.

Outputs are in the form of tables in Microsoft Excel. As the user works through the RBCA model each individual screen can be printed. The output details the exposure routes, the toxicological data and, where the source zone concentration data has been input, whether or not the "target levels" have been exceeded. Alternatively, the user can print a single summary sheet detailing all the input parameters.

The output highlights chemical-specific parameters that have been altered from the default by the user. If any values have been altered from those contained in the chemical database, the user should include a justification for the change as part of the final report together with a printout of the project-specific chemical database.

The output tables in the software are:

- A table of human health risks for individual pathways and a table of cumulative risk (note that the UK Department of Health does not accept cumulative assessment of risk unless the contaminants are acting on the same target organ)
- A table of steady-state contaminant concentrations at the exposure point (if analytical groundwater modelling has been conducted)
- A table of "cleanup standards" for each contaminant and each media evaluated (i.e. soil and groundwater)

In addition, for the risk value calculation mode the software also provides the following outputs:

- **Risks by individual pathway.** These tables present the average daily intake and baseline risk calculations for each complete exposure pathway and associated receptors (on-site, off-site1 and off-site2):
 - outdoor air
 - indoor air
 - soil
 - groundwater
 - surface water
- **Risks by all pathways.** This table presents a summary of baseline risks for all selected pathways. A solid red box indicates pathways for which target risk limits are exceeded. The user can later assess the target risk limits depending on the context within which the risk assessment is conducted

For the "cleanup standards" mode the following types of tables can be selected:

- **Result summary by individual COC.** This is a summary of RBSL or SSTL values together with the chemical, toxicological and natural attenuation parameters used in their calculation. Applicable media "cleanup standards" are identified by values displayed in bold italics
- **Individual constituents by affected media.** This output screen presents a summary of calculated Tier 1 RBSLs or Tier 2 SSTLs for all COCs, organised by affected source medium (soil and groundwater)
- **Multiple constituents.** In order to compute SSTLs based on cumulative risk effects, RBCA provides an interactive calculator for adjusting individual constituent target levels to meet cumulative risk goals (i.e. total risks from all contaminant exposure not to exceed 1 in a million). The cumulative risk worksheet only applies if the affected soil or groundwater zone must be remediated to meet a cumulative risk limit (i.e. an upper bound carcinogenic risk or hazard index for the combined effects of multiple constituents). The worksheet lists all COCs and displays individual and cumulative risk values for each applicable exposure medium and receptor. If the applicable cumulative risk limit is exceeded for a given exposure medium, the user may then adjust constituent reduction factors (CRFs) (i.e. the representative COC concentration divided by the applicable target concentration) until the desired cumulative risk level is achieved.

Model interpretation

What does the output mean?

From the Tier 1 and Tier 2 assessment two primary types of outputs are derived using this model:

- risk values
- cleanup levels

The Tier 1 values are screening values and should not be used as remediation values. These values are non-site-specific and are based on conservative exposure factors, and fate and transport parameters.

The Tier 2 assessment can generate both risk values and "cleanup levels". These levels are based on site-specific information and parameters. As part of the Tier 2 assessment a constituent reduction factor (CRF) is generated which indicates what level of contaminant reduction would be required to ensure that the contaminant levels do not exceed a specified cumulative "target risk level".

As noted earlier, the Department of Health does not support cumulative risk levels unless the COCs are acting on the same target organ. The RBCA toolkit does not make a distinction as to which target organs are being impacted. Therefore, the user should be aware that although the software may highlight risk levels or SSTLs as being exceeded, it does not necessarily mean that the site is causing unacceptable levels of risk. In order to determine if in fact this is the case, the user should seek an expert toxicologist's advice.

Supporting information required to use the model appropriately (input data requirements)

The following is a list of information required to conduct a comprehensive risk assessment using the RBCA Tool Kit. Some of the parameters can be obtained from published literature. However, to conduct a site-specific assessment the following data should be collected from the site:

- source area
- soil porosity
- depth of contamination (top to bottom)
- depth to groundwater
- groundwater gradient
- groundwater flow direction
- hydraulic conductivity
- potentially affected receptor types
- distance to off-site human receptor
- distance to surface water / groundwater receptor
- impacted media
- contaminant concentrations in each impacted media

Common problems with the model

- The programme sometimes crashes due to changes made in the chemical database while running a simulation
- The chemical database for each project has to be saved separately from the rest of the programme and copied into the programme folder every time the project file needs to be altered
- Sometimes the programme does not recognise that all the appropriate boxes have been checked on the screen and does not allow the user to move onto the next step
- Calculations for the inhalation exposure result in different values when comparing the forward and backward modes due to the use of, and conversion of, the inhalation unit risk concentrations
- Sometimes the unit conversion is not saved when the user changes it.

Common mistakes made when using the model

- The RBCA Tool Kit conceptual model and the site-specific conceptual model do not match and therefore the assessment would be incorrect (e.g. site grows vegetables but RBCA does not evaluate vegetable uptake and subsequent human consumption)
- The NC abbreviation is sometimes found in the output tables, indicating contaminants for which RBSLs or SSTLs could not be calculated. This is usually due to a lack of toxicological or physico-chemical data. This does not mean that the particular contaminant and exposure pathway can be ignored, but indicates that there are uncertainties with the assessment due to the lack of data
- The ">Csat" symbol is sometimes part of the results table generated by the RBCA Tool Kit. This symbol is usually generated by the software to indicate that risk levels are not exceeded at a concentration above the saturation level for soil or groundwater. This means that even if free product was encountered it would not cause adverse effects via that particular exposure pathway
- Using an erroneous soil porosity
- Using the default values provided within the programme for soil types, which are based on US soils and not UK soils
- Not adopting the UK context for exposure parameters, drinking water standards and toxicological data
- Using inappropriate "target risk" levels
- Confusing the on-site and off-site receptors
- Not including all the input and output data as part of the report.

Model limitations – what the model does not do

The following list summarises the model limitations:

- The model is not capable of simulating contaminant concentrations down-gradient of a discharge point for surface water
- The model does not allow probabilistic human health risk evaluation
- The Tool Kit only addresses indoor air exposure for the on-site receptor. Therefore, this model cannot be used to migrate volatiles to an off-site receptor and the subsequent intrusion of volatiles to off-site buildings

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- The model is a US-based model and must be adapted to the UK context
- The UK considers surface soils to consist of the first 0.5 metres, while RBCA uses 0–1 metre [6]
- The “target risk” levels used in RBCA is a maximum excess cancer risk of 1×10^{-4} which equates to an annual risk level of 1×10^{-6} . However, it is important to note that this differs from the UK approach [3].

Sensitive model parameters

- Source area – The source area is an important parameter because it is this area that determines the amount of vapours available for indoor and outdoor receptors
- Soil porosity – Use of a small soil porosity value will retard the contaminant migration in soils
- Hydraulic gradient – This is important in determining how fast a contaminant plume may be moving to an off-site receptor
- Hydraulic conductivity
- Degradation factors – These will influence how quickly a contaminant is transformed or degraded
- Toxicological parameters such as reference doses (RfD) and slope factors (SF)
- Building-crack factor – This has a major impact on the vapour regimes for the indoor receptor

Other parameters which will influence the model results are the exposure parameters used for the different exposure pathways. These should be in line with current site use and/or UK statistical values. Some of these parameters have been summarised as part of the Contaminated Land Exposure Assessment (CLEA) model [4].

References and further information

- [1] American Society for Testing and Materials (ASTM) (1995) Risk-Based Corrective Action (RBCA) E1739-95 Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.
- [2] American Society for Testing and Materials (ASTM) (2001) Risk-Based Corrective Action (RBCA) (E2081-00) Standard Guide for Risk-Based Corrective Action.
- [3] Defra and the Environment Agency (2002) *Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans*. Report CLR9. Published by Defra and the Environment Agency. Available from WRC, Frankland Road, Swindon,

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- [4] Defra and the Environment Agency (2002) *Toxicological Reports for Individual Soil Contaminants*. Report TOX1-10. Published by Defra and the Environment Agency. Available from WRC, Frankland Road, Swindon, Wilts SN5 8YF. Also downloadable from the Defra website – www.defra.gov.uk.
- [5] Health and Safety Executive. *EH40/02 Occupational Exposure Limits 2002*. Health and Safety Executive. ISBN 0 7176 14743.
- [6] Defra and Environment Agency (2002) *The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms*. Report CLR10. Published by Defra and the Environment Agency. Available from WRC, Frankland Road, Swindon, Wilts SN5 8YF. Also downloadable from the Defra website – www.defra.gov.uk.

Further information

Further details on the application of this model and other risk assessment models can be obtained from: Environment Agency, National Groundwater and Contaminated Land Centre (NGWCLC), Olton Court, 10 Warwick Road, Olton, Solihull, B92 7HX (Tel: 0121 708 4714, Fax: 0121 708 4637).

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