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case study bulletin

CL:AIRE case study bulletins provide a source of information on the characterisation and remediation of specific sites in the UK. This case study bulletin details the technical development of the Atkins ATRISK^{soil} soil screening values, the key technical challenges and how GAC should and should not be used.

The Development of Risk Based Generic Assessment Criteria (GAC) for Assessment of Chronic Human Health Risks from Exposure to Soil Contaminants

1. INTRODUCTION & BACKGROUND

This bulletin describes the on-going technical programme of human health risk assessment and toxicological research which Atkins has undertaken since 2003 and which has led to the generation of the most recent set of Atkins Generic Assessment Criteria (GAC), termed ATRISK^{soil} Soil Screening Values (SSVs) and Water Screening Values (WSVs), for the initial assessment of chronic human health risks from exposure to contaminants within soils and groundwater. The ATRISK^{soil} SSVs and WSVs are GAC (as defined in CLR11) for which Environment Agency Soil Guideline Values (SGVs) are not available. They have been derived using generic assumptions about the characteristics and behaviour of sources, pathways and receptors which have been defined within published Environment Agency guidance and used in the derivation of the published SGVs[1].

Defra and the Environment Agency first published the Contaminated Land Exposure Assessment (CLEA) framework in 2002 including ten SGV reports which replaced the previous trigger and action threshold values developed by the Inter Departmental Committee for the Redevelopment of Contaminated Land (ICRCL). The SGVs were intended for use during preliminary assessments of both planning and Part 2A sites. As only ten SGVs were initially published there was a significant gap in the availability of screening values for other contaminants for both contaminated land practitioners and regulators. Atkins initially embarked on the ATRISK^{soil} SSV development programme to provide consistent and technically robust screening values for company use. However, it soon became apparent that regulators, particularly Local Authorities, would benefit significantly from access to the ATRISK^{soil} SSVs, pending the intended release of a more comprehensive suite of SGVs. More information on ATRISK^{soil} SSVs can be obtained from www.atrisksoil.co.uk.

A number of changes have been made to the CLEA framework since its release and Atkins has updated the ATRISK^{soil} SSVs to take these changes into consideration. This bulletin details the technical development of the Atkins ATRISK^{soil} SSVs, the key technical challenges and how GAC such as the ATRISK^{soil} SSVs and WSVs should and should not be used. These technical challenges and the questions over suitability for use of GAC are not unique to Atkins and will have been encountered by the other organisations which have developed their own human health GAC. Within the bulletin the development of Atkins WSVs, which are used as GAC to assess risk to human health from chronic exposure to contaminants in perched water or shallow groundwater, is also presented along with ideas for further research.

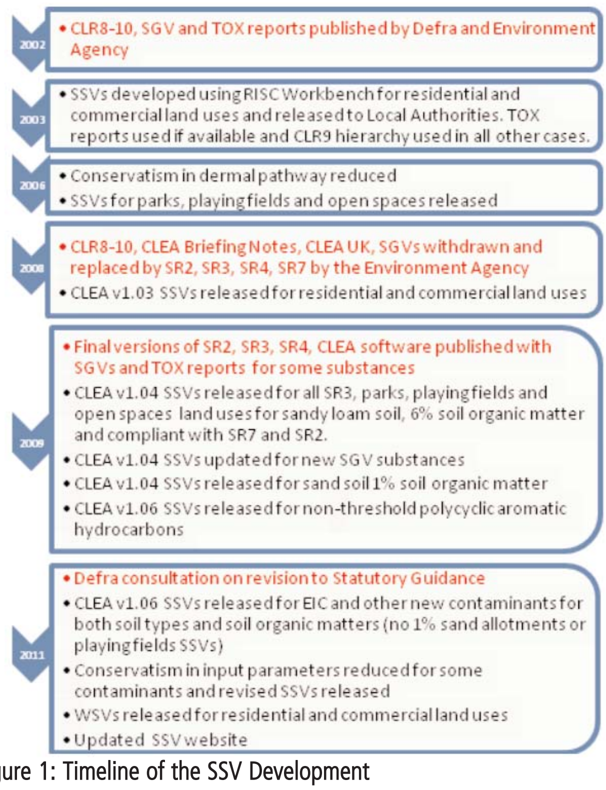

Figure 1: Timeline of the SSV Development

[1]The Atkins ATRISK^{soil} SSVs are human health SSVs and should not be confused with the ecological soil screening values introduced within the Environment Agency 2008 report 'Guidance on the use of soil screening values in ecological risk assessment', Science Report SC070009/SR2b

2. SSV DEVELOPMENT

The ATRISK^{soil} SSVs have been developed for a suite of contaminants commonly found on brownfield land for which SGVs have not been published. The values have been continuously reviewed to ensure that they remain compliant with new published guidance, including new toxicological reports, guidance in frequently asked questions on the Environment Agency website and new underlying algorithms. They are intended to be used in an equivalent way to the SGVs and other available GAC.

Figure 1 shows a timeline of the ATRISK^{soil} SSV development since 2003. In 2009 the ATRISK^{soil} SSVs were updated to be compliant with changes to the CLEA guidance. These included:

- Adopting the approach to physical chemical data published within SR7, involving calculations to derive data for those compounds not included in SR7;
- Deriving toxicological values using the SR2 guidelines, which are more onerous than those in the previously used CLR9, as SR2 provides a list of data sources to check as a minimum and also requires the application of professional judgement in decision making. Care was taken to ensure that only genotoxic carcinogens were classed as index dose compounds, that it was appropriate for dermal exposure to be compared to the oral health criteria value and that the dermal absorption factor applied was appropriate for the compound being assessed. In some cases, the potential for dose addition from different chemical isomers or via the same mode of action from members of the same chemical family was also considered;
- Use of CLEA v1.04 to v1.06 software, as applicable, to model ATRISK^{soil} SSVs; and
- Incorporating, where applicable, default parameters for soil types, building types and receptors.

Case Study: Applying the right Conceptual Exposure Model (CEM) to provide rapid site assessment at low cost

Approximately 200 residential properties, a school, commercial buildings and a woodland area of local importance were investigated on behalf of a Local Authority under Part 2A. The Health Protection Agency and Primary Care Trust were involved early in the project and accepted the use of the SSVs in initial screening.

For each area of the site, a CEM was developed considering the relevant sources, pathways and receptors. The CEMs were used to establish whether the SSVs were appropriate for use for each area of the site. The most relevant set of SSVs was selected to assess each area. The ability to use SSVs based on a relevant CEM meant that areas of no further concern could rapidly be identified at the initial stage of assessment, reducing the requirement for further investigation and detailed quantitative risk assessment.

3. DEVELOPMENT OF GAC FOR THE STANDARD AND NON-STANDARD LAND USES AND SOIL TYPES

Standard CLR10/SR3 Land Uses

The ATRISK^{soil} SSVs were originally developed for three of the default land uses presented within CLR10: residential with the consumption of vegetables; residential without the consumption of vegetables; and commercial and industrial. Default values were used and where CLR10 presented a range of values, appropriate single point values were selected using time averaging. In SR3, which superseded CLR10 in 2008-9, a number of changes were made to the default parameters for the standard land uses. The ATRISK^{soil} SSVs were updated in line with these and ATRISK^{soil} SSVs were also developed for the allotment land use.

Broadening the Land Use Offered

Further ATRISK^{soil} SSVs were developed for parks, playing fields and open spaces land uses which although not covered in CLR10 are commonly encountered. This was undertaken to avoid over-conservatism in the initial assessment through the misapplication of the standard land uses by providing a set of GAC which reflected more accurately the Conceptual Exposure Model (CEM) and potentially reduced the requirement for an unnecessary stage of detailed quantitative risk assessment (DQRA). Data were collected through visiting, observing and distributing questionnaires at such sites in order to characterise receptors and estimate their behaviour. The data were used to develop a generic CEM and select appropriate input parameters. The parks, playing fields[2] and open spaces ATRISK^{soil} SSVs were published in July 2006. After publication of SR3, from which these additional land uses remain absent, in 2009, the CEMs and ATRISK^{soil} SSVs were updated taking into account relevant information.

Which Soil Type is Most Representative of Made Ground?

The 2009 SGVs are available for a 6% soil organic matter (SOM) sandy loam soil. For many brownfield sites this assumption regarding soil organic matter is not appropriate due to the prevalence of Made Ground in which the SOM is often very low due to the high content of materials such as clinker and brick rubble. In addition, Made Ground is often composed of more permeable material than assumed for a sandy loam soil. These parameters are of particular importance for the inhalation pathway. Hence GAC based on a 6% SOM sandy loam soil are not likely to be protective on sites where substantial Made Ground is present. Therefore, after taking into account feedback from subscribers, a set of ATRISK^{soil} SSVs were developed for a sand soil (the closest soil type to a typical Made Ground within SR3) with 1% SOM for the key land uses. Allotments were not included within this set as it was considered that a very permeable soil with a low SOM would not be conducive to plant growth and so not representative of typical allotment soils.

Soil Gas Ingress Rate

The default SR3 soil gas ingress rate for a residential property used in the SGVs was designed to be protective of a range of building types with a sandy loam soil. However this may not be protective for properties constructed on sites with more permeable soil types such as Made Ground or a sand soil. Therefore it was considered more appropriate to use a specific soil gas ingress rate calculated for the two-storey building type with a sand soil.

[2] The playing fields SSVs are modelled for four critical receptor groups and the lowest assessment criterion is selected for each contaminant.

Learning Point: Indoor vapour algorithms and suspended wooden floors

The CLEA framework assumes that properties have a concrete floor slab, with cracks around the edges. However, many older residential properties in the UK have suspended wooden floors for which the algorithms within CLEA are not appropriate. Published suspended wooden floor algorithms, which also often only assume cracks around the edge of the floor may not be sufficiently protective, as experience has shown that additional holes and gaps are often present in wooden floors - for example from installation of radiators, gaps between floor boards, knot holes and services.

In such instances, more specific measurements such as vapour monitoring may be required to provide an accurate assessment rather than relying solely on the CLEA framework to assess the indoor inhalation pathway.

4. KEY TECHNICAL CHALLENGES

The CLEA framework radically changed in 2008-9 and is likely to be subject to further changes by the proposed revision of the Part 2A Statutory Guidance (laid before Parliament in February 2012). The draft Statutory Guidance (Defra, 2012) states that Defra considers the level of conservatism within the 2009 SGVs to be such that they lie within Category 4 i.e. equate to "*levels of contamination at which risks are likely to be negligible or minimal*". Figure 2 provides an example of the proposed classification scheme described within the draft Statutory Guidance. SGV/GAC are also viewed as unsuitable as generic remediation targets applicable to brownfield development for a Part 2A or a planning scenario[3]. Consequently, by reducing conservatism wherever possible, whilst remaining consistent with the relevant technical framework (SR2 and SR3), a more widely applicable set of planning screening values could be generated.

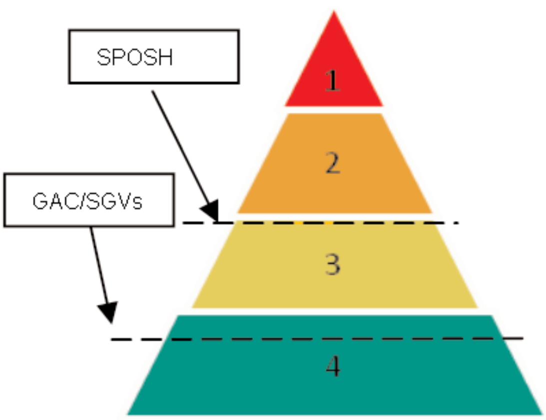

Figure 2: Schematic Representation of the Proposed Statutory Guidance Classification.

In light of this expected policy development, Atkins has re-evaluated some assumptions used in the ATRISK^{soil} SSVs and updated them to reduce conservatism where reasonably possible, focussing on a re-assessment of both the toxicological and physical chemical parameters[4]. Consequently a series of changes have been made in 2011 including:

- Reduction of mean daily intake (MDI) for some contaminants where new data are available. Reducing the MDI increases the intake allowable from soils and thus increases the ATRISK^{soil} SSV;
- Modification of the Health Criteria Value (HCV) selected for some contaminants where more recent or relevant data were available. Increasing the Tolerable Daily Intake (TDI) increases the ATRISK^{soil} SSV;
- Modification of the subsurface soil to indoor air correction factor for petroleum related substances (using guidance in the benzene, toluene, ethylbenzene and xylene SGVs and CIRIA VOC handbook (Baker *et al.*, 2009)) to account for the over-estimation by the Johnson and Ettinger algorithms, which is commonly ascribed to the absence from the model of hydrocarbon vapour biodegradation in aerobic environments. Decreasing the concentration reaching the indoor air, increases the ATRISK^{soil} SSV; and
- The 2009 ATRISK^{soil} SSVs for a range of organic compounds were set conservatively at concentrations where, in theory, free phase contamination could be present, to act as a trigger for more detailed site specific assessments to be undertaken. In the 2011 updates, the revised ATRISK^{soil} SSVs for organic compounds assume that free phase contamination is not present and so are derived solely from the health risk based outputs from the CLEA software model. This has resulted in higher and more pragmatic values for these compounds.

5. ATRISK^{soil} SSVs FOR LESS COMMONLY ENCOUNTERED CONTAMINANTS

To develop ATRISK^{soil} SSVs for contaminants less commonly encountered, such as pesticides, the approach taken has been to use the technical guidance given in the SR2 and SR7 reports in order to derive suitable toxicological and physical chemical parameters for use in the CLEA software. Expert toxicological judgement is critical to this process as in many cases for more unusual contaminants a *de novo* approach is required to provide values. Technical expertise is also used to select and perform appropriate calculations for physical chemical parameters which are not present in SR7 or most, if any, of the SR7 sources. Where there is insufficient toxicological information for a specific compound, no GAC can be produced as expert judgement should be applied on a site specific basis.

6. CONSIDERATION OF OTHER AVAILABLE SOIL SCREENING VALUES

At the present time, SGVs are only available for 11 substances. Whilst many commercial organisations have their own 'in house' GAC, there are currently only three published sources of soil GAC publicly available for UK use; one set is published by the Environmental Industries Commission (EIC) in association with the Association of Geotechnical and Geoenvironmental Specialists (AGS) and CL:AIRE and is freely downloadable from the CL:AIRE website, one is made available commercially by LQM in association with CIEH and the final set is the ATRISK^{soil} SSVs made available commercially by Atkins Ltd. The justifications and rationale for selection of the input parameters are available from the relevant organisations. Four examples of the differences between the Atkins ATRISK^{soil} SSVs, EIC/AGS/CL:AIRE and LQM/CIEH values (from Atkins' internal comparison) are presented in Table 1.

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[3] "*in relation to ensuring that land affected by contamination does not meet the Part 2A definition of contaminated land after it has been developed*"

[4] More information can be found on www.atrisksoil.co.uk which is regularly updated.

Atkins' direct comparison[5] has shown that in the majority of cases, the LQM/CIEH GAC and the Atkins ATRISK^{soil} SSVs are within an order of magnitude of each other (some above, some below) which illustrates that, although different professional opinions can be applied, the resulting assessment criteria do not differ widely from each other especially when considered in light of other uncertainties in the risk assessment process. Small differences can be found where critical physical chemical properties or toxicological values are found to differ, and thus it is inevitable that criteria will differ. However, in each instance, where different values have been selected, the decisions made can be justified and supported by reputable reference data sources, details of which are available from the relevant organisations.

Table 1: Main differences between Atkins SSVs, EIC/AGS/CL:AIRE GAC and LQM/CIEH GAC

LQM has used literature data to estimate plant uptake for some metals, whereas Atkins has used the PRISM (Thorne *et al.*, 2005) algorithms. SR3 indicates that using PRISM or undertaking appropriate literature searches may both be acceptable approaches[6].
Atkins has used data published by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) and adapted to soil temperature to calculate physical chemical properties for TPH fractions. LQM has also used data from TPHCWG as the basis for physical chemical data but has undertaken additional literature review (as detailed in the LQM documentation).
Different K_d values have been selected by Atkins and LQM/CIEH for metals as different sources have been selected. In each case, the selection has been appropriately justified and details are available from the relevant organisations.
EIC/AGS/CL:AIRE GAC and LQM/CIEH GAC are only available for the SR3 standard land uses and for a sandy loam soil type[7]. The Atkins SSVs are available for the SR3 standard land uses and three public open space land uses, for a sandy loam soil with a SOM of 6% and a sand soil with a SOM of 1%[8].

7. INTRODUCTION OF HUMAN HEALTH WATER SCREENING VALUES (WSVs) FOR VOLATILE CONTAMINANTS

The current scope of the CLEA guidance does not address the potential health risks associated with a sub-surface water source containing volatile contaminants which may result in a pollutant linkage through both indoor and outdoor vapour inhalation. It is common for water concentrations to be compared to drinking water standards (DWS) or to simply be excluded from the human health risk assessment, but to be evaluated through a separate hydrogeological risk assessment process (Environment Agency, 2006). The DWS are often based on oral, rather than inhalation, toxicological assumptions with consideration of taste, odour and colouration. In some cases the values derived may not be sufficiently protective of human health via inhalation exposure routes. Hence the use of the DWS to assess inhalation risks may not be an appropriate substitute for deriving human health sub-surface water GAC.

Atkins has derived WSVs for two land uses: commercial; and residential, in line with SR3 indoor vapour algorithms using the GSI Risk Based Corrective Action (RBCA) Toolkit software version 2.5 which was adapted to be UK compliant. These two land uses were selected as the critical inhalation of vapours indoors pathway is present. The CEM used in the ATRISK^{soil} SSVs incorporated (where appropriate) a shallow depth to groundwater of 1 m such that the Atkins WSVs would be applicable to most sites at the initial assessment stage. Where the saturation limit was exceeded, the contribution of the aqueous solubility to the hazard quotient for each pathway was calculated and professional judgement was applied as to whether and how to combine the exposure from the indoor and outdoor vapour pathways in the context of the impact on the result. For some contaminants with a high air water partition coefficient, the depth to water can be a significant input parameter and for sites where exceedances of GAC are noted, further site investigation and/or risk assessment should be considered.

Case Study: Method for deriving GAC for use in planning for unusual contaminants

A former pesticides manufacturing site was intended for redevelopment as residential housing after appropriate remediation. ATRISK^{soil} SSVs were not available for all the pesticides identified at the site and a series of specific values were derived. The process of deriving ATRISK^{soil} SSVs entailed establishing a CEM suitably conservative for use under planning, deriving relevant HCVs compliant with CLR9*, grouping pesticides, selecting values for the most sensitive and deriving physical chemical parameters.

The use of ATRISK^{soil} SSVs provided a preliminary indication of the extent of the site which might require remediation. This led to early consultations with contractors on the cost-effectiveness of a number of potential remedial techniques, enabling the developer to manage their cost and programme risks more effectively. The ATRISK^{soil} SSVs informed the remedial options appraisal and the outline remediation strategy which was developed through consultation with the Local Authority and Environment Agency. The remediation strategy in turn underpinned the planning application made to the Local Authority, which resulted in the developer successfully securing planning permission for the remediation and redevelopment of the site.

* This project was completed prior to the publication of SR2 (which replaced CLR9).

[5] The 1% SOM and sandy loam SSVs were compared to the 1% SOM and sandy loam LQM/CIEH GAC and the 6% SOM SSVs were compared to 6% SOM GAC.

[6] More detail on the use of PRISM can be found in the technical queries section at www.atrisksoil.co.uk

[7] It should be noted that where appropriate contaminant data are available (e.g. published in SR7, Environment Agency toxicological reports, EIC/AGS/CL:AIRE and LQM/CIEH reports and the ATRISK^{soil} website) it is relatively straightforward, given a basic level of competence with the CLEA software, to produce GAC values for other soil types or conceptual models.

[8] SSVs for a sand soil are not available for all land uses e.g. allotments.

8. PITFALLS AND LESSONS LEARNT DURING THE DEVELOPMENT PROGRAMME

Thorough and detailed QA/QC is one of the most important tasks within GAC development. Hence to minimise the potential for calculation errors, the ATRISK^{soil} SSVs were derived in duplicate as on occasions, within Microsoft Office 2007, different computers have provided different results from the CLEA software, for instance when a function or the conditional formatting failed to work. Detailed checking of all calculations was an integral part of the process, as was checking of input parameters against output parameters. Additionally, the individual oral and inhalation assessment criteria for different ATRISK^{soil} SSV sets were compared to each other e.g. the outputs from parks to open spaces, 6% SOM sandy loam soil type to 1% SOM sand soil type. The ratio difference between the comparisons was then evaluated to identify anomalies. In many instances, the ratios can be considered in their contaminant groupings and patterns form e.g. polycyclic aromatic hydrocarbons (PAHs) all behave similarly within a certain range. Key differences in ratios can be explained through consideration of the contribution of pathways and may reflect a higher dermal or background exposure.

Case Study: Application of a relevant CEM

A human health risk assessment at a residential development and playground on a former landfill (thought to contain municipal waste) was undertaken to inform the Part 2A process on behalf of a Local Authority.

An initial human health risk assessment was performed using ATRISK^{soil} SSVs for residential land use with the consumption of homegrown produce and park land use. Using ATRISK^{soil} SSVs for a variety of land uses allowed the assessment to consider the site's varying sensitivities, while maintaining a robust and cost effective approach and not being over-conservative. Application of the different ATRISK^{soil} SSVs was also consistent with the averaging areas used within the assessment. Following the completion of the risk assessment, it was agreed with the client and regulator that no unacceptable risks were present such that the previously anticipated remediation was no longer required.

9. USE AND MIS-USE OF GAC

Instances of where GAC have been used in circumstances for which they were not designed include:

- when free phase product is at surface;
    - o GAC may not be sufficiently protective of the dermal and ingestion pathways[9]
- for assessment and determination under Part 2A;
    - o GAC are not representative of a significant possibility of significant harm
- as import criteria;
    - o just because the risk based value for a GAC is e.g. 900,000 mg/kg is it appropriate to import soils with that quantity of contaminant (noting it would also represent free phase);
- when the GAC CEM does not match the actual CEM of the site;
    - o if the receptor spends twice as much time on the site as assumed in the CEM, then exposure assumed in the GAC underestimates the exposure upon the site.

10. SUGGESTED FURTHER WORK / RESEARCH

There are a number of areas where additional work or research has the potential to reduce conservatism further so that the ATRISK^{soil} SSVs and other GAC will be of greater value in distinguishing between sites where mitigation measures are justified and those where the risks are acceptably low. Priority areas for additional research effort include:

- **Additional land uses**: feedback has indicated that GAC for additional land uses would be helpful. Such land uses include: schools; hospitals; residential care centres; and open space land adjacent to houses. Research could be conducted to establish reasonable receptor behaviour for such land uses;
- **Risk driving pathways**: the risk driving pathway for some metals and PAHs is the inhalation of dust tracked back indoors. Research projects could improve on the limited data available to establish whether or not the estimated concentrations in dust actually occur on sites in the UK; and
- **bioaccessibility:** the British Geological Survey has recently published a paper for bioaccessibility for lead, arsenic and cadmium with *in vivo* data (Wragg *et al*., 2011). Research is underway for benzo(a)pyrene; however, there are currently no *in vivo* data published with which to demonstrate that the laboratory tests suitably mimic *in vivo* processes.

Learning Point: Don't forget the site observations!

The CLEA framework assumes dermal absorption through the skin is from contact with soil to which contamination is sorbed. Free phase product is likely to pass through the skin faster and in greater quantities; thus the SSVs will underestimate exposure. In some cases, the oral HCVs are not based on ingestion of free phase product and the potential toxicity is underestimated in the HCV. Free phase product can also indicate a wider problem across a site, such as leakage from an unknown tank.

Isolated exceedances of the open spaces TPH aliphatic C12-C16 SSVs were identified at an area of land adjacent to a railway line. The risk driving pathway was identified as the inhalation of vapours outdoors, based on an exceedance of the saturation limit rather than a risk based value. This initiated further evaluation of the borehole logs and site observations which revealed small quantities of an oily based substance close to surface. As such, further evaluation was required considering the dermal pathway rather than solely the inhalation pathway.

[9] Vapour monitoring should always be considered / evaluated when the concentration of a VOC exceeds the SSV. Theoretically, where the vapour saturation limit is exceeded and the hazard quotient is less than 1, the predicted soil vapour concentration cannot be high enough to cause an unacceptable risk.

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