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Review

The Development and Use of Sustainability Criteria in SuRF-UK's Sustainable Remediation Framework

R. Paul Bardos [1,2,*], Hayley F. Thomas [3], Jonathan W. N. Smith [4,5], Nicola D. Harries [6], Frank Evans [7], Richard Boyle [8], Trevor Howard [9], Richard Lewis [10], Alan O. Thomas [11] and Angela Haslam [9]

1 R3 Environmental Technology Ltd., Reading RG6 6AT, UK
2 School of Environment and Technology, University of Brighton, Brighton BN2 4AT, UK
3 Shell Global Solutions International B.V., 2288GS Rijswijk, The Netherlands; Hayley.thomas@shell.com
4 Shell Global Solutions (UK) Ltd., London SE1 7NA, UK; jonathan.w.smith@shell.com
5 Groundwater Protection & Restoration Group, University of Sheffield, Sheffield S10 2TN, UK
6 CL:AIRE, London WC1B 3QJ, UK; nicola.harries@claire.co.uk
7 National Grid Property, Warwick CV34 6DA, UK; Frank.Evans@nationalgrid.com
8 Homes England, 2 Rivergate Temple Quay, Bristol BS1 6EH, UK; richard.boyle@homesengland.gov.uk
9 Environment Agency, Bristol BS1 5AH, UK; trevor.howard@environment-agency.gov.uk (T.H.); angela.haslam@environment-agency.gov.uk (A.H.)
10 WSP Remediation, London WC2A 1AF, UK; richard.lewis@wsp.com
11 Environmental Resources Management, Oxford OX2 0QS, UK; alan.thomas@erm.com
* Correspondence: paul@r3environmental.co.uk; Tel.: +44-118-378-8164

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Abstract: Sustainability considerations have become widely recognised in contaminated land management and are now accepted as an important component of remediation planning and implementation around the world. The Sustainable Remediation Forum for the UK (SuRF-UK) published guidance on sustainability criteria for consideration in drawing up (or framing) assessments, organised across 15 "headline" categories, five for the environment element of sustainability, five for the social, and five for the economic. This paper describes how the SuRF-UK indicator guidance was developed, and the rationale behind its structure and approach. It describes its use in remediation option appraisal in the UK, and reviews the international papers that have applied or reviewed it. It then reviews the lessons learned from its initial use and the opinions and findings of international commentators, and concludes with recommendations on how the indicator categories might be further refined in the future. The key findings of this review are that the SuRF-UK framework and indicator guidance is well adopted into practice in the UK. It is widely recognised as the most appropriate mechanism to support sustainability-based decision making in contaminated land decision making. It has influenced the development of other national and international guidance and standards on sustainable remediation. However, there is room for some fine tuning of approach based on the lessons learned during its application.

Keywords: contaminated land; sustainable remediation; sustainability assessment; risk management; brownfields; indicators

1. Introduction

Despite much progress, significant work remains in tackling the global land contamination legacy and its public health and environmental impacts. A recent study for the European Commission found an annual management cost of contaminated sites in the European Union of ~€3 billion [1]. A 2012 estimate for overall remediation costs for the known contaminated sites in the USA was $110–127

billion [2]. The 2017 global market for environmental remediation technologies is estimated to be US$68 billion [3]. These costs represent complex site management effort, and it is important that this effort is made as sustainable as possible.

Contaminated land is managed to mitigate the risks it poses to human health, ecology, water, or other receptors [4]. The international consensus is that risk-based land management provides the best available framework for decisions because (1) it provides an objective way to link actions to the prevention of harm, e.g., to human health or the wider environment; (2) it provides a rationale for how to intervene, i.e., which source–pathway–receptor linkages need to be broken to successfully mitigate unacceptable risks; (3) moreover, it provides a rationale to prioritise limited resources at the most serious/urgent problems/problem sites [5–7]. What sustainable remediation constitutes is sustainable and risk-based management, which broadens the risk management outlook to ensure that reducing the potential for harm from land contamination avoids also unintentional consequences (e.g., emissions to air/water or excessive use of materials and energy), and is also broadly beneficial to society [8].

Over the past 10 years, consequent to the initiation of the first Sustainable Remediation Forum (SURF) in the USA in 2006, sustainability considerations have become more widely recognised in contaminated land management. It is now widely accepted as crucial to remediation planning and implementation around the world [9–12]. Many countries have established sustainable remediation networks which are linked to a central international platform, International Sustainable Remediation Alliance (ISRA), which can be accessed from www.claire.co.uk/isra.

A range of sustainable remediation frameworks and guidance documents have now been published around the world, along with a rapidly growing peer-reviewed journal literature. Sustainable remediation standards have also been published (ASTM, 2013) [13], and most recently ISO, 2017) [14], which consolidates international state of practice on approaches and sustainability assessment in the context of remediation option appraisal [10].

Sustainability is a broad concept which is usually understood by aggregating information about individual indicators [15,16]. Sustainability assessment requires a set of individual criteria to be agreed by those carrying out an assessment, which is relevant to the project and stakeholder perspectives.

In 2011 the Sustainable Remediation Forum for the UK (SuRF-UK) published guidance on sustainability criteria (also referred to by SuRF-UK as "indicators") for consideration in drawing up (or framing) assessments, which acts as a checklist. These criteria are organised across 15 "headline" categories, five for the environment element of sustainability, five for the social and five for the economic, as shown in Table 1 [17]. The SuRF-UK indicator checklist remains the most comprehensive and detailed guidance to support the selection of sustainability assessment criteria for sustainable remediation planning and option appraisal from any of the current international sustainable remediation networks [9] and its headline categories are replicated in the ISO Standard [14]. This approach is based on the Brundtland Definition of "sustainable development" [18].

Table 1. SuRF-UK Headline Categories for Indicators [17].

Environmental	Social	Economic
Emissions to air	Human health and safety	Direct economic costs and benefits
Soil and ground conditions	Ethics and equity	Indirect economic costs and benefits
Groundwater and surface water	Neighbourhoods and locality	Employment and employment capital
Ecology	Communities and community involvement	Induced economic costs and benefits
Natural resources and waste	Uncertainty and evidence	Project lifespan and flexibility

This paper describes how the SuRF-UK indicator categories were selected, and the rationale behind its structure and approach. It describes its use in remediation option appraisal in the UK, and reviews the international papers that have applied or reviewed it. The paper then reviews the lessons learned from its initial use in the UK and the opinions and findings of international

commentators, and concludes with recommendations on how the indicator categories might be refined in the future.

2. The SuRF-UK Framework for Sustainable Remediation

SuRF-UK is essentially a series of projects supported by a constituency of different practitioners: Regulatory bodies, public agencies, industry and other site owners, consultants and contractors, researchers, developers, and planners. It was established by CL:AIRE after a broad consultation of UK practices in the mid 2000's [19]. CL:AIRE (www.claire.co.uk) is an independent not-for-profit organisation established in 1999, by a number of Public and Private Sector Bodies, to stimulate the regeneration of land in the UK by raising awareness of, and confidence in, practical and sustainable remediation technologies. CL:AIRE have acted as the secretariat for SuRF-UK since its establishment in 2007 to "develop a framework to embed balanced decision making in the selection of a remediation strategy to address land contamination, as an integral part of sustainable development". It has been supported by a Steering Group over this period, whose current membership are the authors of this paper.

In 2010, SuRF-UK published a framework for assessing the sustainability of soil and groundwater remediation [20], which was accepted by all the relevant UK national regulatory and other public bodies. This document defines sustainable remediation as "the practice of demonstrating, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than its impact, and that the optimum remediation solution is selected through the use of a balanced decision making process". The framework, shown in Figure 1, identifies two stages where sustainability assessment for remediation can influence decision making. These are during project conceptualisation and design (for example, when considering the layout of a site and how it will be used post-remediation; called "Stage A" in the framework), which is when risk management requirements and hence remediation objectives are set; and also after remediation objectives have been set ("Stage B") when the decision is about finding the optimal means of reaching a given set of defined remediation objectives. It is widely thought that the earlier sustainable remediation design can be considered in this decision making process, the greater the chance for greater sustainability "gains" [21,22].

Clearly, to "manage" the sustainability of remediation, i.e., to compare and select the optimal remediation solution, and then to determine how to verify its performance, some form of sustainability assessment is required. SuRF-UK's approach has been to suggest that these decisions should be based on the simplest form of sustainability assessment that produces a reliable management decision, and that in most cases a *qualitative* assessment is sufficient [23]. If qualitative assessment indicates no clear preferred remediation option, or is questioned by one or more stakeholders then it may be necessary to go for a *semi-quantitative* approach (i.e., one based on scorings and weightings). Fully *quantitative* approaches, such as a (monetised) cost benefit assessment, would only be needed if the semi-quantitative assessment also fails to find a resolution. This tiered approach is illustrated in Figure 2. However, as sustainability assessment progresses through these tiers it can lose both transparency (for example because of embedded approximations and assumptions) and have a reduced scope (as analyses cover a smaller range of sustainability considerations) [22]. In particular, cost-benefit analyses may suffer from a number of difficulties relating to transparency, scope, and the reliability of the valuation process, and may therefore not be persuasive to all stakeholders [24]. Furthermore, valuations may be complex and technically challenging [25]. Stakeholder dialogue and engagement is recognised in the SuRF-UK Framework as a key element in developing robust sustainability assessments, not least because there is no such thing as an absolute and objective measurement of sustainability. Processes of engagement and dialogue are explicitly included in SuRF-UK's more detailed guidance on sustainability assessment [26]. Another important facet of achieving sustainability is good working practices on site. This is explicitly recognised in Figure 2 as "Tier 0" for sustainable management procedures, for which detailed guidance has also been developed by SuRF-UK [27].

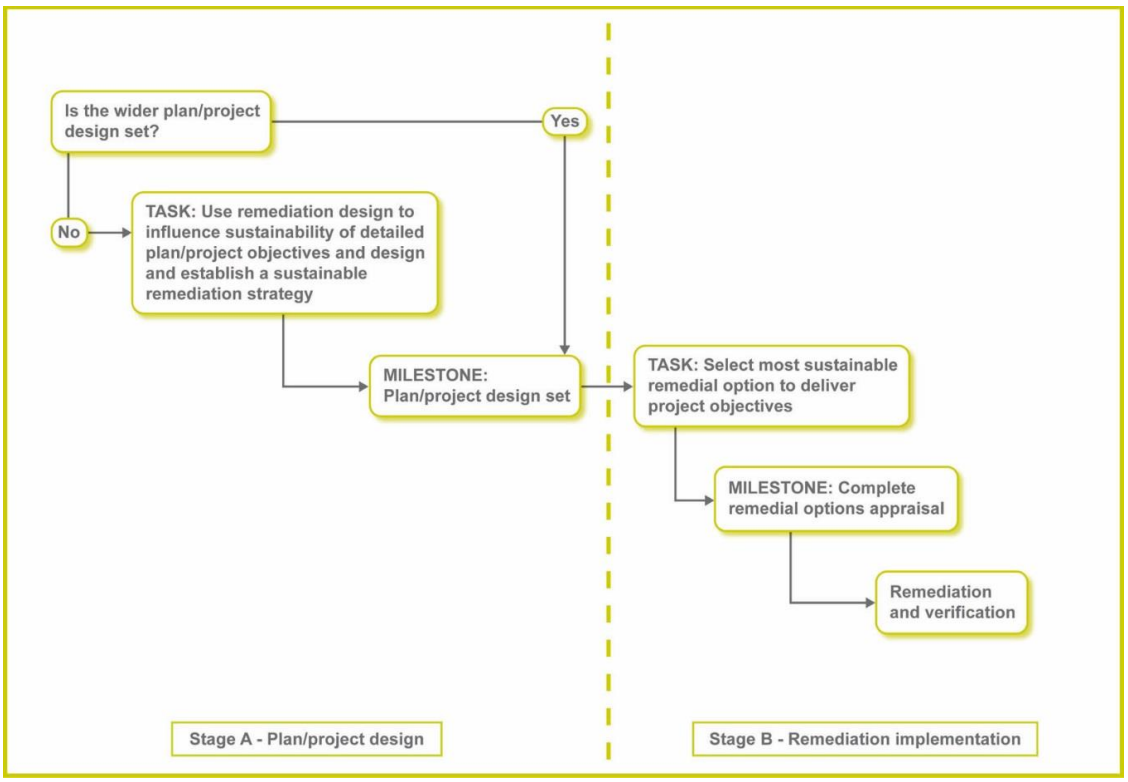


Figure 1. Overall schematic of the SuRF-UK Framework (© CL:AIRE 2010 [20]). Reproduced with permission.

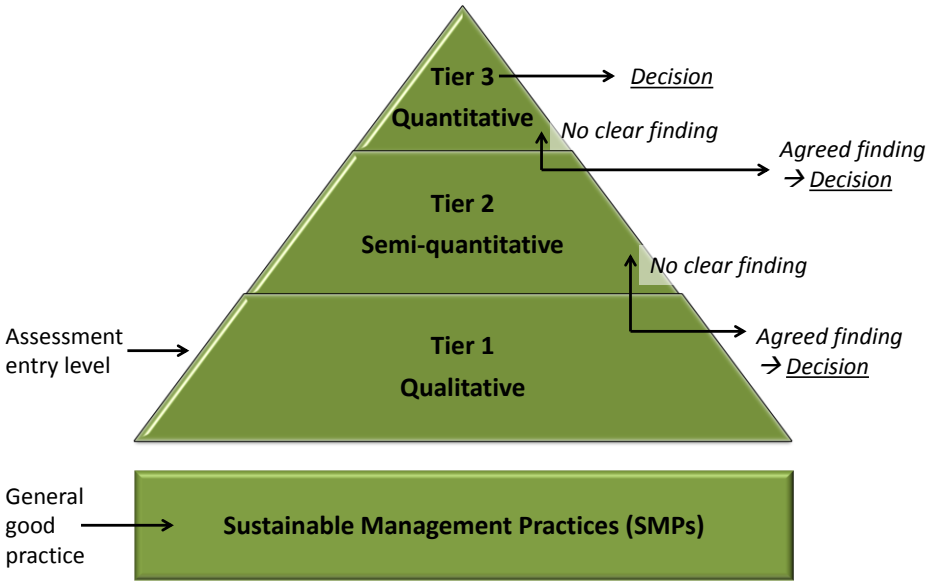


Figure 2. A tiered approach to sustainability assessment (© CL:AIRE 2014 [26]). Reproduced with permission.

In 2014, SuRF-UK released more detailed guidance on how to "frame" and carry out sustainability assessment using its framework, including a summary briefing [26] and downloadable presentations and templates, all freely available from www.claire.co.uk/surfuk. The framing of the sustainability assessment consists of two stages: Preparing the assessment, and defining how it will take place (Figure 3). These stages must be clear and robust before sustainability assessment is carried out to ensure a reproducible sustainability assessment approach. This three-step approach is in line with good practice for sustainability appraisal in the UK planning and development sector [28]. The assessment

may be iterative, for example, to include wider stakeholder opinions and perspectives as a project progresses. Particularly important in the definition of the sustainability assessment approach is documenting an agreed set of boundaries and an agreed scope that applies to all the options being compared to ensure like is compared with like. SuRF-UK sustainability indicators are key in forming a common understanding of the meaning and scope of each indicator, and its potential overlap with others. To date, none of the other national sustainable remediation initiatives have published a similar checklist [10], although some, such as SuRF-ANZ have adopted it. The US Environmental Protection Agency (EPA) has published guidance on assessing what it terms "Green Remediation" [29], which is broadly in line with the environmental headline categories SuRF-UK has identified (shown in Table 1).

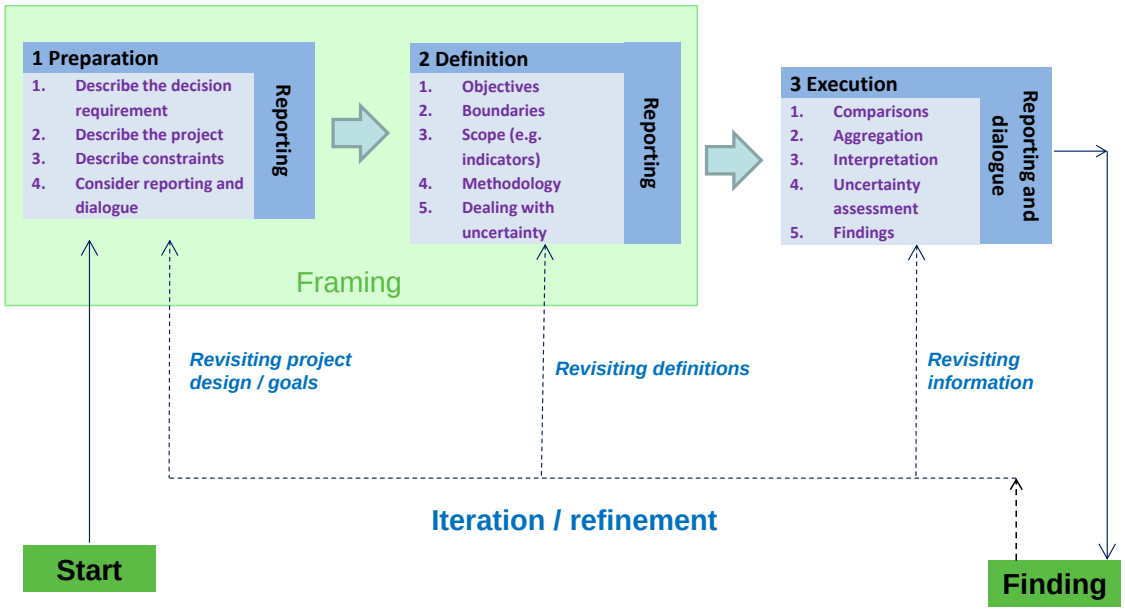


Figure 3. Sustainability assessment and its framing (© CL:AIRE 2014 [26]). Reproduced with permission.

Green remediation, as defined by the US EPA, is a concept based on the wider environmental impacts of remediation, and is predicated on the view that under the US Federal Superfund Program issues relating to economic and social sustainability will already have been considered prior to a remediation decision [9]. Attempts have been made to reconcile this with the wider and more complete domain of sustainable remediation by using the term "Green and Sustainable Remediation" (GSR) [12], albeit some leading advocates consider this term inappropriate [10], for instance because "sustainable remediation" already encompasses the "green" or environmental element of sustainability. The focus of this paper, however, is on the indicator guidance SuRF-UK has developed for the wider domain of sustainable remediation as defined above.

3. The Development of SuRF-UK's Indicator Guidance

SuRF-UK's development of guidance on sustainability assessment indicators/guidance began in 2009 when it published a review of a large number of sustainability indicator sets and their relevance to contaminated land management [30]. Over 100 documents describing sustainability indicators (for a wide variety of purposes) were identified and reviewed and a total of 2421 individual indicators were identified, which were mapped to 18 broad headlines, six for each of three elements of sustainability. Within this body of work, no pre-existing and *comprehensive* set of sustainability indicators/criteria explicitly for contaminated land management was found. Twelve indicator sets (with 265 indicators in total) ascribed to contaminated land management were found. However, the coverage of these indicator sets on an individual basis across the 18 broad categories was incomplete. For example, eight indicator sets did not include consideration of impacts on soil. It was not clear why this should be,

and SuRF-UK considered this a significant deficit. From an early stage, soil and ground function was seen as a critical category of sustainability by SuRF-UK, which was and is consistent with current policy. In 2017, the Food and Agriculture Organisation of the UN (FAO) published Voluntary Guidelines for Sustainable Soil Management [31], in line with the UN Sustainable Development Goals or SDGs, discussed below. The importance of soils to sustainable development, and the potential threats to good soil function, are also highlighted by the European Soil Thematic Strategy [32], the UK Department for Environment, and Food and Rural Affairs (DEFRA) Soil Strategy for England [33], and are seen as underpinning at least nine of the UN SDGs [34]. Clearly these relate to soils not sealed by buildings or infrastructure. However, in the case of construction that seals soil, re-use of brownfield land reduces the sealing of soils on virgin sites, which is seen as an increasing concern across Europe [35,36].

Initial suggestions for sustainability indicators for remediation were put forward at an open stakeholder meeting in 2008 [19]. These suggestions were fairly evenly distributed across the three elements of sustainable development (environmental, economic, and social). However, within each element, most indicator choices were clumped around particular choices, which were strongly related to landowner and regulator interests (impacts on air, resource utilisation and waste management, indirect and direct costs, community involvement and satisfaction, human health, and impacts on neighbourhoods or regions). The indicators identified by the literature review were wider ranging in the aspects they covered.

SuRF-UK's conclusions from these exercises were that, firstly, there was no "off the shelf" set of sustainability criteria that it could deploy to the support the framework it was developing. Secondly, there was a stakeholder appetite for holistic sustainability assessment for remediation projects, but an incomplete understanding of the full scope of what sustainability assessment might cover. Thirdly, an initial indicator guidance or checklist could be developed from its review of existing sustainability assessment indicator guidance and indicator sets.

Therefore, as an interim position, the 2010 framework document [20] included an initial categorisation list (18 broad categories) used to group indicators for the purposes of cross-comparison in the 2009 review report [30]. Work to develop and refine indicator guidance to support the Framework continued over 2010–2011. SuRF-UK held three open meetings at different locations in the UK, which were attended in total by over 100 practitioners of different types (site managers, consultants, contractors, public agencies, and academics) [19]. Each workshop used a series of three case studies of sustainability assessments for remediation option appraisal using a range of methods and indicators (the same for each workshop), which were then discussed and debated by the delegates. These exercises were used to get a practitioner view on sustainability assessment, including the selection of sustainability indicators/criteria. These were collated and adapted in a spreadsheet checklist, based on one already used for one of the case studies. The spreadsheet checklist was reviewed and refined regularly at a series of Steering Group meetings over 2010/11, and published in 2011 [17]. One of the most substantive changes from the 2010 outline position in the Framework document [20] was the rationalisation of headline categories, reducing these from 18 to 15, five per element of sustainability (environmental, social and economic). The distribution of an equal number of headline categories for each element of sustainability was deliberate, to clearly communicate that no one element was a dominant consideration.

The SuRF-UK indicator guidance is advisory. The headline indicator categories and checklist of individual considerations relate to both relative benefits and relative detriments.

The consultation work that supported its development also showed a clear preference from the UK practitioner community that they did not think a definitive set of criteria would be helpful, as sustainability is highly specific to site, project, and the stakeholders involved. Instead, what is offered is a checklist to assist assessors in defining a broad scope, reminding them what they might be omitting, but not demanding particular criteria should be included. This checklist was supplemented in 2014 with a package of guidance measures about how to frame and carry out sustainability assessment, which provided further advice on how to use the checklist [26]. This included the suggestion that the

optimum way to use the checklist was to assume any consideration listed *is relevant* unless there is clear evidence or reasoning to the contrary, agreed by all the stakeholders involved in the assessment. The reasons for non-inclusion should be recorded. Equally, it is possible that the checklist does *not include* a consideration that stakeholders involved with a particular assessment feel is necessary. In this case it is suggested that the consideration should be included, again with a rationale recorded.

4. Practical Use of SuRF-UK's Indicator Guidance within the UK

The SuRF-UK Framework is now in regular use in the UK, as it is cited in a number of guidance documents related to remediation option appraisal, in particular [37,38], as well as there being a strong presumption to sustainable development in wider planning policy [39–41]. Three case studies are provided on the SuRF-UK web site, all relatively early examples:

- Case Study 1—Sustainability Assessment: Former fuel depot, Madeira [42] which used seven of the headline categories as indicators, weighting the others to zero.
- Case Study 2—Upper Heyford—Remediation Options Appraisal [43], which used the 15 headline categories as indicators in combination with technical feasibility scores as a basis for remedy selection.
- Case Study 3—Helpston Contaminated Land Project [44], which used seven of the headline categories as indicators.

Table 2 lists other UK examples of the use of the SuRF-UK framework, including the use of the indicator guidance. This table was collated by the SuRF-UK Steering Group on the basis of published information, grey literature, and the authors' knowledge of UK industry activity. Some of this information was unpublished and intentionally anonymised. Guidance published by UK regulators means that all contaminated land remediation decision making should consider the sustainability of the measures being put in place. In practice site owners, service providers, and site managers will look to established approaches shared by a community of interests, especially if related to a standard, as this is an easier platform for achieving consensus. Therefore, while it is not possible to indicate what proportion of UK projects across the whole contaminated land management sector are represented by Table 2, the listing is substantial, and part of a general trend to consider sustainable remediation.

Table 2. UK examples of SuRF-UK framework use.

Project Name	Location	How SuRF-UK Framework Was Applied and How Indicators Were Considered
Port Sunlight Riverside Park appraisal	Port Sunlight (Merseyside)	Retrospective investigation of the sustainability gain from establishing a public park on a former landfill site. The checklist was used in detail to develop a conceptual site model of sustainability and sustainability assessment against a hypothetical baseline [45].
NanoRem UK case study	South England	Comparison of nanoremediation with other in situ methods for remediation of an organics contaminated site. They considered all 15 headline categories and used the checklist to support this broad category comparison [46].
Retail filling station #1	Eastern England	Sustainability assessment of electrokinetic bioremediation compared with alternative remediation options for a petroleum release site [47].
Retail filling station #2	Central England	A benchmarking study compared sustainability assessments across all tiers of sustainability assessment (qualitative, semi-quantitative and quantitative) using the full range of SuRF-UK headline indicators. Rankings were generally consistent across the three methods [48].
Retail filling station #3	Eastern England	Sustainability assessment undertaken, including participatory stakeholder session, to inform best remediation strategy at a site regulated under Part 2A of the Environmental Protection Act 1990 [Contaminated Land regime].
Using a hybrid LCA method to evaluate the sustainability of sediment remediation	London Olympic Park	This study combined life cycle assessment with the use of a quantitative assessment of social and economic indicators, based on the SuRF-UK indicator set, to rank options for the management of dredged materials [49].
Environment Agency	England	Consideration of the SuRF-UK framework and supporting information has been incorporated into corporate procedures and guidance on regulating the management of land contamination. This includes references in internal guidance on dealing with consultations on planning documents and external guidance (e.g., refernce [37]).
International Oil Company—National retail filling station network	UK	Routine application of the SuRF UK indicator set within sustainability assessment for remedial technologies identified as feasible during remedial alternatives assessments.
Multinational company	UK	Use of SuRF-UK SMP checklist resulted in program-wide decisions to: direct all hydrocarbon-contaminated soils to waste treatment facilities (zero landfill); apply (and measure) CO_2 reduction objectives to remediation projects; better planning/combining of fieldwork to minimise road-miles.

Table 2. *Cont.*

Multi-national utility company	UK-based	Established a set of Sustainable Management Practices that all on-site land regeneration activities in UK are required to be evaluated against, in order to embed sustainable decision making into all activities irrespective of scale. This approach is based on SuRF-UK Toolkit SMP practices and Indicator set.
Multinational Manufacturing Client	UK	Use of SuRF-UK indicator sets to populate multi-criteria assessment to support remediation evaluation of former chemical processing site. The objective of the assessment was to further develop technological options appraisal whilst developing close out objectives based upon measurable factors.
Multinational Company	Northern England	Application of SuRF-UK guidance through lifecycle of a remediation project. SuRF-UK indicator set used to compare remedial alternatives.
Multinational Company	Southern England	SuRF-UK indicator set used in remedial options appraisal using a mixture of qualitative and quantitative scoring for individual applicable indicators.
Multinational Company	Northern England	Use of SuRF-UK indicator set as basis for a multi criteria analysis of remedial options undertaken in context of a roundtable workshop with key stakeholders for the remedial options appraisal at a manufacturing site.
Various	UK	Routine application of the SuRF UK indicator set within sustainability assessment for remedial technologies identified as feasible during remedial alternatives assessments.
Multinational Company	UK, Europe, the Middle East and Africa	Consideration of SuRF-UK indicator set together with a number of corporate sustainability metrics to develop a broader sustainability assessment across a portfolio of sites. Encouraged and tracked use of SMPs at every stage of the project life cycle.
Multinational Chemical Manufacturer	UK	Use of SuRF-UK indicator sets to populate multi-criteria assessment to support remediation evaluation of former chemical processing site. The objective of the assessment was to further develop technological options appraisal whilst developing close out objectives based upon measurable factors.

5. Benchmarking SuRF-UK's Indicator Guidance

In 2015, the United Nations published a series of 17 *Sustainable Development Goals* (SDGs), representing an intergovernmental consensus and integrated list of 169 sustainability targets [50]. Table 3 maps these UN SDGs to the SuRF-UK indicator categories. There are direct linkages to 13 of the 17 SDGs. It is not surprising that there are no direct linkages to some, but there are indirect linkages as explained below:

- *Goal 1: End poverty in all its forms everywhere*—there is an indirect association between this goal and sustainable remediation across many of the SuRF-UK headline categories in that (a) a more efficient land cycle can provide a wide range of wider economic benefits (ECON1/2/3—*see* Table 3 *for explanation of these abbreviations*), including stimulating inward investment (ECON4). It is not uncommon for areas in the vicinity of industrial and brownfield sites to be relatively poor [51] and the removal of blight can improve both their health (SOC1) and the local circumstances (SOC3), although "green gentrification" is becoming an emerging concern [52] (SOC2).
- *Goal 10: Reduce inequality within and among countries*—sustainable remediation assessments tend to be site based. However, the framework created has important considerations that could also be drawn at national/regional level (SOC5).
- *Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development* —Marine resources have not been explicitly listed in the "Annex 1" guidance. However, they could be a material consideration at coastal sites, in which case stakeholders can, if they wish, extend the ENV3 category to consider them.
- *Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development*—The UN SDGs are not (as yet) referenced in the SuRF UK Indicator guidance. However, the existence and work of SuRF-UK, as well as similar fora in many other countries, advances sustainability in contaminated land management worldwide.

Table 3. SuRF-UK headline categories [18] mapped against examples of potentially-corresponding UN SDGs [50].

SuRF-UK Category	Related SDG(s)	Example Relationships of the SuRF-UK Sustainability Categories with the UN SDG
Emissions to air (ENV1)		Greenhouse gas emissions are an explicit consideration in ENV1.
Soil and ground conditions (ENV2)		Some contaminated sites are treated for "soft" re-use e.g., biofeedstocks reducing land use conflict with agriculture [53].
Groundwater and surface water (ENV3)		Improvement of water resources by reducing risks from contamination.
Ecology (ENV4)		Restoration and protection of ecological system services on brownfield sites, in particular in soil and water.

Table 3. *Cont.*

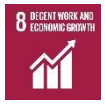
Natural resources and waste (ENV5)		Recyclate use to avoid extraction of virgin resources (e.g., soil/aggregate) [54].
		Encouragement of the use of renewables in remediation practice. Furthermore, the possibility of production of renewables on brownfields [55].
Human health and safety (SOC1)		Reducing risk pathways to humans including via the food chain (for example agricultural land contamination is a major concern in China).
		Creating green spaces on brownfield sites.
Ethics and equity (SOC2)		Management of risks while maintaining social justice, equal access to information and engagement, and a clear regard for the authority of relevant institutions.
Neighbourhoods and locality (SOC3)		Making cities and human settlements inclusive, safe, resilient and sustainable is one of the fundamental goals of contaminated land management.
Communities and community involvement (SOC4)		Adopting an inclusive approach to contaminated land management decision making.
Uncertainty and evidence (SOC5)		Ensuring a strong science based evidence base for sustainable and risk based contaminated land management, to provide resilient solutions.
Direct economic costs and benefits (ECON1)		Management of contaminated land releases sites for re-development.
Indirect economic costs & benefits (ECON2)		Improvement of contaminated sites can positively impact surrounding land values.

Table 3. *Cont.*

Employment & employment capital (ECON3)		Development of jobs and skills related to contaminated land and brownfields management, and also more widely (e.g., reference [56]).
Induced economic costs & benefits (ECON4)		Improvement of amenity and stimulation of investment by brownfields restoration.
Project lifespan & flexibility (ECON5)		Ensure remediation solutions are resilient, robust and flexible over time.

The SuRF-UK indicator categories and checklist highlight a number of wider sustainability considerations, for example relating to ozone depletion and acid rain (ENV1) that are not clearly visible in the UN SDGs, but nonetheless considered very important.

Since 2011, there has been significant activity in the development of general sustainability assessment and associated indicator sets, including the revised UN SDGs and also the OECD well-being indicators [57]. Since the publication of the SURF-UK indicator guidance there have been a number of studies related to the sustainability of brownfields regeneration (e.g., references [58–61]), and cost-benefit and life-cycle based remediation assessments (e.g., references [62,63]) as well as multi-criteria analysis based tools for remediation option appraisal (e.g., references [64,65]). In addition, the USA SURF and the Austrian Environmental Protection Agency published suggested (quantitative) metrics for remediation sustainability assessment [65–67]. Unsurprisingly, none of these represent a substantial digression from the broad scope of sustainability headlines considered by SuRF-UK, but close consideration may offer opportunities for incremental improvement.

6. Applications of the SuRF-UK Indicator Guidance Worldwide

In addition to the applications of the SuRF-UK indicator guidance in the UK, it has also been influential on a more global basis. Table 4 lists a number of these applications. This listing was compiled from an open search of published information, for example available from *Google Scholar*, collated to March 2018.

Table 4. Use of the SuRF-UK indicator guidance worldwide.

Country/Region	Application	Comments
Australia/Fiji 2016	An academic study of how different groups of stakeholders perceive different values for remediation, and that these can change as a project progresses, which took place across four case studies [68].	Sees the SuRF-UK guidance as industry led, and emphasises the importance of social considerations and effective communication in robust community engagement in decision making.
Australia 2015	Development of a simple semi-quantitative method for remediation sustainability evaluation based on Australian and overseas practice and experience [69].	SuRF Australia/NZ drew on the SuRF-UK framework and subsequent documents [70]. This short article describes a case study sustainability assessment using the SuRF-UK indicators.

Table 4. *Cont.*

Australia 2017	Academic review of uncertainties in remediation and their communication between experts and non-experts [71].	Focuses on the social element of the SuRF-UK Indicator set and suggested that a potential limitation is a focus on empirical uncertainty rather than its "mental" form, which appears to refer to how uncertainty is represented to non-experts.
Belgium 2014	Research paper evaluating a range of sustainability appraisal tools for remediation option appraisal. The tools assessed were quantitative in nature and narrower in scope that the SURF-UK checklist [72].	Several operational tools were benchmarked against each other and the SuRF-UK Indicator set. The SuRF-UK guidance is not classed as a tool in this paper which is in line with its checklist functionality.
Belgium 2016	Inclusion of social indicators in decision support tools for the selection of sustainable site remediation options [73]. This work found an imbalance of used indicators still expressing a strong preference for the environmental aspect at the expense of the economic and social aspects of sustainability, the lack of consistency in the terminology used within the field and the failure in adapting released tools to recent legislation or scientific advancements [74].	These papers benchmarked the considerations of five sustainability based decision support tools against the social element of the SuRF-UK indicator set, as a broad ranging schema.
Brazil 2017	Use of the SuRF-UK Framework and sustainability assessment tools for a contaminated area of the University of São Paulo [75].	Operational activities focused on the implementation of Sustainable Management Practices [27] rather than use of indicators in option appraisals.
China 2013	Book chapter that discusses land remediation mechanisms in the US and UK, and how these mechanisms may apply in China [76].	Discusses how the SuRF-UK sustainability framework and indicators might be useful in the Chinese remediation context.
China 2016 *	UK advice on risk management decision making, verification of remediation outcomes, systems of governance and evaluation of costs versus benefits and overall sustainability [77].	Use of the SuRF-UK sustainability assessment. Subsequent to this work, a SuRF-China was established in October 2017.
China 2017	China has an extensive agricultural land degradation issue due to pollution. This paper suggests an approach for a Chinese sustainability assessment framework for agricultural land remediation [78].	Inclusion of SuRF-UK indicators into a suggested indicator set for use in sustainable remediation appraisal in China.
China 2018	Environmental and socio-economic sustainability appraisal of contaminated land remediation strategies: A case study at a mega-site in China [79].	This suggested sustainability assessment indicator set was based on the SuRF-UK indicator set and other sources. However, the authors felt that the SuRF-UK indicators were too broad so proposed a narrower set.
Colombia 2017 *	Sustainability assessment as a tool in contaminated site/brownfield rehabilitation options [80].	Use of the SuRF-UK sustainability assessment.
CZ and UK 2016 *	NanoRem Project (www.nanorem.eu). Site based sustainability assessments of nanoremediation compared with alternatives [46].	Use of the NICOLE Sustainable Remediation Road Map [81] and the SuRF-UK sustainability assessment procedure.

Table 4. *Cont.*

Denmark 2016	Short review of approaches for assessing sustainable remediation, commenting on the limited availability of worked case studies.	Reproduces the SuRF-UK 2011 indicator guidance headline categories [82].
Denmark 2017	Multi-criteria assessment tool for sustainability appraisal of remediation alternatives for a contaminated site [83].	Inclusion of SuRF-UK indicator considerations.
EU FP7 Project 2014 *	Work on the assessment and design of soft reuse interventions and services within brownfield regeneration processes [84].	Suggested use of SuRF-UK Framework and guidance for sustainability assessment in brownfields option appraisal.
Finland 2009	Review of Finnish Ministry Environment guidance for risk assessment and sustainable risk management, which describes methods and indicators for sustainability assessment and the assessment process itself [85].	Made use of the SuRF-UK 2009 indicators survey.
Japan 2017–2018	Presentations made at SURF-Japan Meetings, Tokyo, 15 and 16 May 2018 [86].	The SuRF-UK indicator guidance is being used as a starting point for the development of a sustainability criteria checklist for use in Japan.
Portugal 2013 *	A sustainability assessment was undertaken relating to remedial works at a marine fuel depot on the island of Madeira. This was a 'live' assessment undertaken at a decommissioned facility. It represents a 'Stage B' assessment, reviewing and comparing alternative remediation options.	The sustainability assessment followed the SuRF-UK framework and included use of its headline indicator categories. Seven of the headline categories were agreed as relevant for the site and the others were weighted to zero. This assessment was written up as a SuRF-UK case study [42].
Netherlands 2017 *	Review of sustainability assessment development for remediation and a selection of Dutch case studies [87].	Considers the use of the SuRF-UK indicators from a Dutch perspective.
OECD	Strategic Considerations for the Sustainable Remediation of Nuclear Installations [88].	This report bases its sustainable remediation definition on that of SuRF-UK) and suggests a sustainability management approach including overview indicators.
Poland 2015	A series of papers from a Polish perspective about "social responsibility and science in the innovation economy", co-financed by the European Union under the European Social Fund [89].	This wide-ranging series of papers reviewed in detail the initial 18 headline indicator categories from 2010, in the context of soil threats.
Portugal 2013	A sustainability framework for redevelopment of rural brownfields: stakeholder participation at SÃO DOMINGOS mine, Portugal [90].	The indicators suggested were based on a wide-ranging review of indicators considered relevant to brownfields restoration including the SuRF-UK Indicator set.
Sweden 2015	Development of MCA tool Sustainable Choice Of Remediation (SCORE) for option appraisal, considering key criteria in the economic, environmental and social sustainability domains [65].	Linkage of the SuRF-UK indicators concept to the same sustainability basis used for SCORE.
USA 2016/2017	Social equity is one of the three pillars of sustainability. This report evaluates the social sustainability of five remedial alternatives for the Portland Harbor Superfund Site.	Application of the initial 18 headline indicator categories from 2010 to sustainability appraisal for a sediment remediation project, and subsequently the 2011 set [91–94].

* Work involving one or more of the authors of this paper.

7. Discussion

The studies listed in Table 4 show that SuRF-UK indicator guidance has been used in its own right, or has been influential in the development of further indicator sets for sustainability assessment for remediation and brownfield applications in many countries around the world. Furthermore, it is often perceived as wide-ranging in its considerations, and balanced in terms of given consideration to the economic and social elements of sustainability as well as environmental indicators. This perception is in line with its designed purpose. A number of studies listed in Table 4 describe the lack of measurability of some of the indicator classes as problematic, in particular studies seeking quantitative metrics for sustainability assessment. SuRF-UK is fully aware that some individual indicator suggestions, and indeed some categories, may be hard to directly quantify. However, that does not invalidate them as being legitimate stakeholder concerns for sustainability, which are capable of comparison in qualitative assessment. They are also capable of comparison in semi-quantitative assessments, and even quantitatively in cost benefit assessment, for example, on the basis of surveys of opinions. There is a trade-off between scope and measurability, and SuRF-UK's approach is to start with qualitative assessment to allow for the widest possible scope, which is seen as a robust basis for sustainability assessment [95]. Different choices may be made in other countries where there is a preference for numbers and quantitative measures [9]. However, it is questionable whether quantitative methods provide greater reliability [23] rather than just 'comfort by numbers', and SuRF-UK benchmarking work indicates that they may not even be necessary for many sites [48].

A further criticism that has been raised in a few of the studies listed in Table 4 is that SuRF-UK indicator guidance is top-down, i.e., based on suggestions made by remediation experts and engineers. This is seen as being problematic in two ways, firstly that it may not sufficiently include discourse from Humanities disciplines, and secondly that, for the purposes of community engagement in sustainability assessment, may not be fully representatives of the "values" that impacted communities may wish to convey, or not be formulated in a way that community participants can readily engage with. Furthermore, interaction in describing and communicating values can be educational for both expert and non-expert alike and support constructive engagement [68,71,96–98]. This may be of great value for some particularly sensitive remediation projects. Nonetheless, land contamination may be used as "leverage" for a wider purpose by communities, for example objecting to housing developments. In this situation a constructive and open debate may not be that easy. On the other hand, a structured approach to sustainability assessment and a checklist of indicators may at least help to support structured and objective discussions.

The SuRF-UK indicator guidance is only intended as a checklist, to be developed and refined on a specific basis for each sustainability assessment, but their utility for community engagement is a valid concern. However, they do turn on the extent to which communities are actually influential in remediation decision making. This is highly site specific. SuRF-UK's framework [20] encourages appropriate stakeholder engagement, but leaves the decision on who to involve to the project management team [26], rather than make a prescriptive one-size-fits-all recommendation for all sites and all projects. This is in line with similar initiatives across the world and in line with the consequent 2017 ISO standard on sustainable remediation [14]. The general view is that it is those who are managing a project are best placed to decide who to involve in sustainability assessment, and both the ISO standard and SuRF-UK make clear that there is no absolute sustainable remediation metric. Hence, the sustainability assessment is essentially subjective, and so to be robust or persuasive it must encompass the inputs of relevant stakeholders who will be referring to it. It is also important to note that the SuRF-UK Framework *is voluntary*. It has an added value, for example in that (a) it can be persuasive to regulators in agreeing optimal remediation; (b) it optimises remedy selection and facilitates sustainability gains; and it can assist projects in being timelier to deliver and providing better value. However, it would be pointless to make a procedure for a voluntary approach so onerous that remediation practitioners would perceive that the burden of its execution would outweigh its potential benefits. SuRF-UK's position is therefore one of positive encouragement of broad and holistic

sustainability assessment as a part of contaminated land risk management, rather than dictation of approach.

Community engagement is perhaps most likely to emerge as a vital step in brownfields projects where restoration is centred on some form of public utility, for example as a park, and/or where there is a substantial public investment in the restoration/remediation work to be carried out. An example of such a project is the Port Sunlight Riverside Park (PSRP) by the Land Trust, mentioned in Table 2, where the value of the park to different public constituencies played a major part both in the investment case made to support the project, and in understanding its sustainability benefits [45]. While the sustainability assessment work carried out so far does not yet include widespread stakeholder engagement, it is already evident that there are some significant "missing" items in the social element of the SuRF-UK indicator guidance, namely: cultural impacts and public health. For the PSRP project these are seen as major benefits. While, the SuRF-UK Framework allows for addition of site-specific indicators, it is perhaps fair to argue that these could be important additions to the general checklist. It might also be fair to argue that the indicators have largely derived from discussion of the remediation of operational sites, or brownfield sites for built redevelopment, as this represented the broad initial interests of the SuRF-UK constituency.

8. Conclusions

The key findings of this review are that the SuRF-UK framework and indicator guidance is well adopted into practice in the UK, where it is widely recognised as the most appropriate mechanism to support sustainability-based decision making in contaminated land decision making. It has also influenced the development of national and international guidance and standards on sustainable remediation. However, there is room for some fine tuning of the approach and details, based on the lessons learned during its application. Broadly speaking, the SuRF-UK indicator guidance has achieved its aim of encouraging sustainable remediation decision making to adopt a broad scope for sustainability indicators or criteria in the UK. Its aims in achieving better sustainable management of land is also fully in line with the recently published UK Government 25-year-plan "to improve the environment" [99].

The indicator guidance has exceeded its authors' expectations in terms of the international influence that it has had. Since the publication of this checklist in 2011, there has been a significant number of indicator publications in brownfields and remediation domains worldwide. There has also been some constructive critical assessment of the SuRF-UK indicator guidance in the international peer-reviewed literature, and there has been a growing body of experience in its use in practice, both for operational and built development sites, and for soft (non-built) re-use of brownfields. This practical use has revealed some potential opportunities for improvement. Consequently, over 2018, SuRF-UK is planning to review and benchmark its indicator guidance against publications since 2011, and overhaul its checklist accordingly. This will be combined with a UK consultation exercise and an open invitation for comment to other sustainable remediation networks around the world that take part in ISRA.

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