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Soil quality — Sustainable remediation

Qualité du sol — Remédiation durable

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

Introduction

This document is intended to provide procedures for sustainable remediation. It contains accepted terminology and understanding of the features of sustainable remediation and of means of assessing the relative sustainability of site-specific alternative remediation strategies. Determining what is and is not sustainable remediation at a specific site will be influenced by many local factors and the governance context. Therefore, this document seeks to preserve local flexibility and freedom of action.

Soil quality — Sustainable remediation

1 Scope

This document provides procedures on sustainable remediation. In particular, it provides:

— standard methodology, terminology and information about the key components and aspects of sustainable remediation assessment;

— informative advice on the assessment of the relative sustainability of alternative remediation strategies.

This document is intended to inform practitioners about contemporary understanding of sustainable remediation. It is not intended to prescribe which methods of assessment, indicators or weights to use. Rather, it is intended to inform consideration of the concept of sustainable remediation in a local legal, policy, socio-economic and environmental context.

The scope of this document is restricted to sustainable remediation — that is demonstrably breaking the source-pathway-receptor linkages — in a manner that has been shown on a site-specific basis under a specific legal context to be sustainable.

The concepts of "green remediation" and "green and sustainable remediation" (so called GSR) that in some parts of the world are conflated with sustainable remediation are neither endorsed nor discussed in this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
brownfield
sites which

— have been affected by former uses of the site or surrounding land;

— are derelict or underused;

— are mainly in fully or partly developed urban areas;

— require intervention to bring them back to beneficial use;

— may have real or perceived contamination problems

3.2
environmental justice
combination of environmental rights and environmental responsibilities that asserts that everyone has

— a right to healthy places to live, work, play, learn and enjoy themselves;

— a right to a fair share of nature's benefits and ecosystem services, such as food and water;

— a responsibility to look after the planet for others and for future generations

3.3
indicator
single characteristic that represents a sustainability effect, whether benefit or negative impact, which may be compared across alternative remediation strategies, comprising one or more remediation techniques and/or institutional controls, to evaluate their relative performance

EXAMPLE Greenhouse gas emissions.

3.4
metric
measurement of an *indicator* (3.3)

EXAMPLE Tons/Tonnes CO_2.

3.5
remediation strategy
one or more remediation technologies and associated works that will meet specified contamination-related risk reduction objectives

3.6
remediation technology
technology that pre-processes, processes or post-processes the ground or contaminant as part of risk management

3.7
sustainable development
development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Note 1 to entry: Sustainable development is about integrating the broader expectations of society as a whole of a high quality of life, health and prosperity with environmental justice and maintaining Earth's capacity to support life in all its diversity. These social, economic and environmental goals are interdependent and mutually reinforcing.

[SOURCE: ISO 26000:2010, 2.23, modified — The Note has been modified and the last sentence has been deleted]

3.8
sustainable redevelopment
component of *sustainable development* (3.7) that results in the return to use of abandoned, derelict, underused and potentially contaminated sites in a way that increases their environmental, economic, and social benefits

3.9
sustainable regeneration
component of *sustainable development* (3.7) that reverses the economic, social and environmental decline of places

3.10
sustainable remediation
elimination and/or control of unacceptable risks in a safe and timely manner whilst optimising the environmental, social and economic value of the work

3.11
threshold
limit of acceptability for an indicator that may not be crossed or carries an unacceptable consequence if it is crossed, such as regulatory non-compliance

3.12
unacceptable risk
level of risk that requires remediation

Note 1 to entry: The level of risk could be evaluated by comparison to a numeric threshold or by benchmarking against a narrative definition. Different levels of risk are deemed unacceptable in different countries or even by different laws within a country.

4 Abbreviations

BTU	British Thermal Units
CBA	cost benefit analysis
CCP	climate change potential
ESTCP	Environmental Security Technology Certification Program
GHG	greenhouse gas
GSR	green and sustainable remediation
LCA	life cycle assessment
MCA	multi-criteria analysis
MNC	multi-national corporation
RBLM	risk-based land management
SuRF	Sustainable Remediation Forum
US EPA	United States Environmental Protection Agency
WBCSD	World Business Council for Sustainable Development

5 Sustainable remediation, (re)development and regeneration

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs[1] is considered to constitute sustainable development. In the case of brownfield sites, remediation is a prelude to physical redevelopment and ultimately socio-economic regeneration. Sustainable regeneration provides multiple benefits. For example, it empowers local communities, provides new employment opportunities, enhances the aesthetics of an area and supports environmental justice.

Since remediation often links into the beneficial redevelopment and reuse of a site, sustainable redevelopment is inherently connected with sustainable remediation.[2] Considering the reuse of a site from the beginning of a remediation project is a fundamental component of sustainable remediation, and therefore sustainable remediation may act either as a natural precursor to, or as a subset of, sustainable redevelopment. Much value may be achieved through successfully integrating remediation into the redevelopment process to exploit synergies while minimizing costs and environmental impacts associated with bringing sites back to beneficial use.

6 Risk-based contaminated land management

The concept of RBLM means integrating decisions on the need for remediation, the timeframe within which it should be implemented and the choice of remediation strategy by considering three components[3]:

— fitness for current/intended land use;

— protection of the environment;

— long term care.

RBLM is intended to assist reaching balanced and informed decisions to achieve sustainable land management. The first decision is whether or not the risk posed by land contamination to human health, ecosystems, property or natural resources is deemed by law or corporate policy to merit intervention. Such remediation should be acceptable to those with an interest in its outcome — stakeholders.

Remediation should be reliable and not breakdown uncontrollably in the future. In addition, remediation should not introduce significant new risks and should be effective over the period in which the contamination risks need to be managed.

Sustainable remediation is about how to manage risks that merit intervention and should not be seen as justification for no intervention in the face of such risks.

There might be non-negotiable boundary conditions, such as legal, corporate policy or regulatory requirements, which have to be taken into consideration. Alternative remediation strategies that meet them may then form the focus for the sustainable remediation assessment.

7 Integrated assessments, metrics and evaluations

7.1 General

There are many ways to integrate various dimensions in order to provide a holistic measure to benchmark against the definition of sustainable remediation. A tiered approach allows application of simple sustainable remediation assessments at less complex sites and more sophisticated, costly and perhaps presently contested assessments at more complex sites.

Meaningful sustainability assessment of alternative remediation strategies is possible and should inform robust and reliable project management decisions. This is despite the fact that sustainability may not be measured in simple units, and that an assessment of the sustainability of remediation strategies is necessarily a subjective process at a given point in time and space. Stakeholders should be encouraged to provide their perspectives on the balance of potential impacts and benefits to facilitate consensus.

Sustainability assessment of alternative soil and groundwater remediation strategies[4]-[7] is improved by:

— being limited to those strategies that are likely to achieve site-specific risk-management objectives (i.e. eliminate and/or control unacceptable risks to human health, property, surface or ground water and the environment);

— following a framework for assessment that is consistent with sustainable remediation (see 3.10) by:

  — considering the environmental, social and economic benefits and impacts associated with each option;

  - identifying which of the remediation strategies being assessed provides the greatest overall benefits;
- comparing alternative strategies against a relevant common baseline, e.g. pump and treat, excavation and off-site disposal or do nothing;
- adopting indicators and metrics that capture all significant benefits and impacts while avoiding double-counting;
- adopting a tiered approach, such that the sustainable remediation assessment is proportional to the scale of the project/problem being addressed;
- taking stakeholder opinions and perspectives into account and, where it is practical to do so, engage directly with stakeholders;
- documenting the activities, data, assumptions and decision points to aid transparency (e.g. see ASTM E2876:2013, Clause 8[8]).

7.2 Tiered assessments

A tiered approach may be used, in which simple qualitative approaches are the default and most commonly used tier, and more complex quantitative tiers are applied only when necessary or otherwise justified.

Simple or relatively clear-cut problems require only simple sustainable remediation assessment. As a general rule, the simplest form of sustainable remediation assessment that allows a robust decision to be made should be adopted. On projects where the decision depends on a small number of indicators that can be measured, a more quantitative approach to sustainable remediation assessment may be necessary to help reach a robust and reliable decision.

7.3 Tiered assessment frameworks

A tiered approach to sustainable remediation assessment illustrates how a simple qualitative, semiquantitative or fully quantitative approach may be taken to a given project. In all tiers the initial considerations are the same:

- confirm the project objectives: what question is the assessment being completed to answer?
- confirm the shortlist of remediation strategies: likely to be effective in meeting project objectives;
- identify the relevant stakeholders: who could affect or be affected by the project?
- identify project boundaries: temporal, spatial and lifecycle limits to the assessment;
- select sustainable remediation indicators: agree on the indicators that will form the basis of the sustainability assessment;
- determine how each indicator will be characterized or measured: agree on the metrics;
- agree the assessment techniques: sustainable remediation assessment techniques that will be applied (i.e. the tier and method).

Once these initial issues have been considered, and background information and data collated, the sustainable remediation assessment proceeds using the agreed assessment technique.

7.4 Sustainable remediation assessment techniques

7.4.1 General

Various qualitative, semiquantitative or quantitative techniques may be used to undertake a sustainable remediation assessment, either in its entirety, or partially (Table 1). The boundaries between the tiers are fuzzy. While there may be some overlap between the techniques applied under these three headings, they serve as a useful classification to emphasize that valid assessments may be completed using simple, intermediate or more complex approaches. In general, the effort involved increases in going from qualitative to quantitative assessments. However, users should beware of the danger of focusing on only those parameters that can (easily) be measured. The inherent flexibility of qualitative methods means they are easier to apply in a comprehensive manner.

Table 1 — Examples of techniques that may be useful for sustainable remediation assessment

Qualitative (simple but comprehensive)	Semiquantitative	Quantitative (complex but partial)
Narrative analysis	Pair-wise comparison	CBA
Non-parametric ranking	MCA	LCA
		(Environmental) Footprint Analysis
		Cost effectiveness analysis NOTE This is strictly an economic analysis.

7.4.2 Qualitative

Qualitative approaches do not attempt to put numbers to different remediation strategies within an assessment. Instead, non-parametric or even narrative alternatives to metrics may be used:

— ranking of one alternative against others as being "better", "neutral" or "worse" for a specific indicator;

— a narrative drawn from discussions between stakeholders where alternative remediation strategies are considered and a preferred option selected based on performance against a range of sustainable remediation indicators.

It is generally possible to consider a wide range of sustainable remediation indicators qualitative; but, quantitative data that may be readily accessible for some indicators is not used to its full extent.

Alphanumeric terms may be used in rankings (e.g. 1, 2, 3 or a, b, c) and may be helpful in rapidly identifying patterns, and median rankings may then be considered. However, these labels should not be confused with semiquantitative or quantitative data where some form of estimation (and weighting) has taken place.

7.4.3 Semiquantitative

"Semiquantitative" approaches quantify some, but not all, indicators or they place values and weightings on all options but without fully monetising and quantifying every aspect, for example:

— MCA using scores (i.e. relative performance of an option against a sustainable remediation indicator) and weightings (i.e. stakeholder view on the importance of a particular sustainable remediation indicator) to rank a number of options — typically, an overall rank is derived from the sum of all weighted scores, when compared to other options;

— quantitative analysis of a number of aspects may be applied alongside more qualitative assessment of other factors such as quantitative assessment of the CO_2 footprint and remediation direct cost combined with qualitative consideration of ecological impact and social aspects within a holistic assessment;

— pair-wise comparison involves comparing the relative performance for a given indicator of each candidate strategy against each other and aggregating the outcomes to allow an overall judgment of the alternatives to be made.

7.4.4 Quantitative

Quantitative approaches require metrics to be applied to the sustainable remediation indicators. The metric may be some form of common currency within a CBA, or a physical quantification (mass, energy, time, etc.) within a LCA. While some indicators may be readily quantified, even monetised, it is more difficult for others. It is not uncommon, therefore, to use simpler assessment methods first to separate remediation options that are clearly better than others, and then to use partial-CBA or other quantitative methods to investigate a small number of sustainable remediation indicators that distinguish the remaining options. Using such a tiered approach may improve the efficiency of the assessment process.

Example for a quantitative approach:

— [environmental] "footprint analysis" compares the aggregate environmental footprint of the candidate remediation strategies.

7.5 Holistic sustainable remediation indicator sets

A sustainable remediation assessment undertaken at any tier requires a set of relevant and measureable indicators to compare remediation options. A holistic set of indicators and their metrics, shall be agreed by stakeholders early in the process. The indicators shall reflect all three dimensions of sustainable remediation: environment, society and economy. Example sustainable remediation indicator categories are presented in Table 2. Having an equal number of categories for each dimension ensures the assessment gets underway with a balanced consideration of each dimension. Balance is maintained by not loading the assessment with many categories in one dimension but only a few in another. From these categories site-specific indicators shall be derived. There may be different numbers of indicators derived for each category or even dimension.

Table 2 — Example sustainable remediation indicator categories[7]

Economy	Society	Environment
Direct economic costs and benefits	Human health and safety	Air
Indirect economic costs and benefits	Ethics and equality	Soil and ground conditions
Employment and employment capital	Neighbourhood and locality	Groundwater and surface water
Induced economic costs and benefits	Communities and community involvement	Ecology
Project lifespan and flexibility	Uncertainty and evidence	Natural resources and waste

8 Decision making

8.1 General

Sustainable remediation can involve decisions on an optimum remediation strategy at several points during a site's (re)development or risk-management. The principal points are:

— regional spatial (land-use) planning: consideration of the impact of remediation alongside other relevant indicators on the sustainability of different land-use allocations during regional spatial planning and redevelopment activities;

— site specific master planning to ensure the allocated uses on a site are laid out in the most appropriate and efficient manner;

— searching for possibilities of synergy between land use and remediation (e.g. groundwater remediation in combination with aquifer thermal energy or soil excavation in combination with providing underground parking);

— design of site characterization strategies, e.g. by:

  — focusing site characterization to aid assessment of possible source-pathway-receptor linkages by improving the conceptual site model;

  — minimizing journeys to site for numerous poorly-planned phases of site investigation;

— using of non-intrusive technologies and preventing new contamination, for example avoid drilling through low-permeability confining layers;

— remediation strategy design: selection of a remediation strategy (i.e. source treatment, pathway interception or receptor modification) that can satisfy essential requirements, including an acceptable level of risk with respect to undertaking the remediation works and long term safety of the site, and optimizes the net benefits of risk-management actions;

— remediation strategy selection: selection of a strategy that can satisfy essential requirements and achieve risk-based remediation goals;

— design of remediation verification strategies, including post-remediation monitoring and communication to the community;

— collection of data to verify a sustainable remediation assessment.

This means that the intention of achieving a remediation outcome that helps optimize the environmental, social and economic benefits of sustainable redevelopment does not rely only on selecting the most sustainable remediation technique. The extent to which contamination drives or is subservient to the decision making varies. In master planning skill sets and professions (e.g. architects, transport planners, education provision) should be considered in addition to those that consider contamination.

8.2 Project framing

Project framing[9] involves establishing the project objectives, boundaries and constraints that need to be met, obeyed and considered respectively in selecting a remediation strategy.

Regulators may specify particular mandatory requirements, such as contamination concentration remediation goals or deadlines for completion of remediation. Broader requirements may also be specified in legislation; for example that the land shall be suitable for its next use.

8.3 How to identify a sustainable remediation approach

To maximize the sustainable remediation benefits, sustainability factors should be considered when making project decisions from the earliest stages of a project. The earlier sustainability is part of decision making the better. There are two key stages at which sustainability can be considered from objective setting to execution:

— Goal-setting stage: involves design of law and policies, regional and local spatial plans, and site-specific master-planning. This stage sets the broad social, economic and/or environmental aspirations that an individual (remediation) project should contribute towards. Examples could include requirements to take account of international climate agreements and regional goals on CO_2 emissions reduction. These aspects are outside the scope of this document and of remediation as a whole. An assessor should understand the goals to be achieved. The most important steps with respect to a sustainable remediation project are made here, and the largest sustainability benefits are created (or lost) at the objective setting stage.

— Design and execution stage: is the stage at which a sustainable remediation strategy is identified and implemented (i.e. how the risk-management goals can be achieved in a sustainable manner). This stage is the main focus of this document.

Larger sustainability gains can be achieved by early consideration of sustainability factors, and inclusion in high-level objectives and policies as well as integrating remediation with other project activities.

Figure 1 illustrates the phases that form a part of the execution stage. In this subclause, only the objective setting stage is addressed.

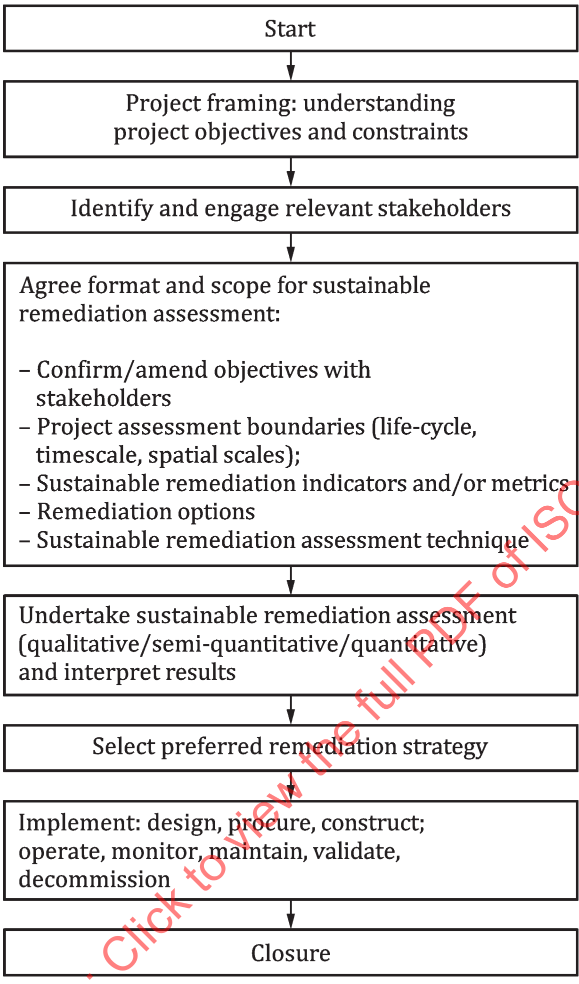

Figure 1 — Stages of sustainable remediation strategy assessment, selection and implementation

8.4 Key principles in decision making

8.4.1 Principles

Key principles should be met during decision making and implementation in order to be able to claim at the end of the process that the remediation is as sustainable as it can be, given the project boundaries and constraints. The following key principles can be defined and should be adhered to:

— the legal requirements for the remediation, and how they apply, have been identified;

— no unacceptable risks, as defined in the relevant law, to human health or the wider environment remain after completion of the remediation activity;

— no unacceptable risks to worker (or nearby community) safety created by the remediation activity;

— transparent decision making processes based on evidence and sound science have been followed;

— good governance and stakeholder involvement have been adopted.

It is essential that the remediation achieves the defined requirements and, in particular, the application of any candidate strategy option is able to achieve relevant protection of human health and the environment.

Remediation strategies are unable to provide an adequate level of protection and should be screened out early in the decision making process.

8.4.2 Stakeholder engagement

The engagement of stakeholders is an important part of a valid sustainable remediation assessment. Stakeholders directly or indirectly affect, or are affected by, the site specific remediation activities. They are an important source of information, and some may be directly involved in decision making (e.g. the site owner and regulator). Others may not have a direct involvement but may still be influential (e.g. neighbours and the local community). Inclusive decision-making processes form part of good governance and reduce the possibility that decisions be revisited in the future. Stakeholder engagement facilitators can help to provide access to the wider community.

In some instances, stakeholder engagement processes can slow down decision making; increase the costs of reaching decisions; and result in a need for technical training of non-specialists.

Stakeholder engagement should generally be proportional to the size of the project under consideration and the breadth of community (or societal) interest. For small and simple projects stakeholder engagement may be limited to site owner, their professional representatives and local authorities with decision-making powers (e.g. planning authority, environmental protection agency). For larger, more complex or controversial projects, much wider stakeholder engagement and dialogue may be appropriate.

8.4.3 Selection of relevant indicators

The selection of indicators includes individual environmental, economic and social concerns important for a project. Involving stakeholders in the selection of indicators may increase their commitment and acceptance of the resulting assessment output. The Bellagio Principles initially proposed by the International Institute for Sustainable Development[10] deal with four aspects of assessing progress toward sustainable development and can be helpful in selecting relevant indicators. During the assessment, stakeholders may:

— adopt indicators;

— discard indicators;

— add indicators, and place these in groupings of similar or related considerations.

8.4.4 Assessment of agreed indicators

Each point in the site remediation decision making process should include a review for the site stakeholders and to ensure mandatory requirements are being met. Assuming that these requirements will be met or are likely to be met, the overall environmental, social and economic impacts associated with the available options can then be assessed. This assessment can be based on qualitative or quantitative methods. In this assessment process, the gains and losses are weighted. The factors of sustainability are usually translated into measurable and comparable indicators (see Figure 2) (see References [7],[11] and [12]).

8.4.5 Selection and implementation

Once a sustainable remediation strategy has been identified, it may be implemented. Further sustainability gains may be achieved during the implementation phase by the use of best or sustainable management practices (see References [9] and [13]). In addition, the use of remediation optimization techniques may be effective in improving system efficiency in a manner that:

— reduces the environmental footprint of the treatment system and operation;

— reduces the social impacts of the treatment system and operation;

— reduces the life-cycle cost of the remediation.

Sustainability gains can be made at all stages of implementation, which typically includes: design, procurement, construction; operation, monitoring, maintenance, remediation verification, decommissioning and closure.

9 Economic dimension

9.1 General

Land contamination is an economic externality arising from historic industrial and waste management practices. Recently, a less monetised view of economics[14] has emerged that sees, but struggles to quantify, the value to society of ecosystem services.

The economic aspects of remediation have traditionally been the focus of both voluntary and enforced action. Polluters, other responsible parties and/or developers have sought the lowest cost remediation that fits with their project objectives and framing.

Purely in terms of cost, remediation involves capital expenditure, mobilization and setting up, maintenance and operation, and finally decommissioning. The costs of verification and ongoing monitoring are incurred in parallel or after the main remediation effort.

An important aspect is comparing remediation strategies' economic performance over the lifetime of the remediation, and how costs are distributed over time by using Net Present Value calculations. Some technologies involve high short-term expenditure, while others incur lower annual expenditure over a longer period of time.

In addition, the way project risk is monetised will influence the apparent relative economic performance of remediation strategies.

9.2 Economic indicators

While there is no universally agreed inventory of economic indicators, the positions of various authorities and other authors reveals considerable overlap, and are summarized as broad categories of indicators in Table 2.

In purely cost terms, remediation projects are built up from:

— preparation, design and permitting;

— capital expenditure;

— mobilization and construction;

— operation (including verification);

— waste management;

— importing materials;

— care and maintenance;

— dismantling and decommissioning;

— asset disposal (to recoup costs by selling surplus or redundant equipment).

Other economic factors include, but are not limited to:

— job creation (including issues of local residents, level of skill);

— land use restrictions;

— uplift in land values (on or nearby the remediation site);

— cost of borrowing;

— costs of deferring reuse of land;

— cost of temporary business/industrial interruption;

— cost of temporary relocation;

— (demonstration) value of successfully executing the remediation;

— risk of damaging existing buildings and infrastructure;

— avoidance of fines or punitive action;

— impact on reputation and brand value.

10 Social dimension

10.1 General

The remediation of contaminated sites, from small-scale neighbourhood sites to large urban or peri-urban sites, very often has an important social impact with significant implications for individuals and for communities.

Remediation of land contamination is an important public and environmental health protection process with associated social well–being implications. The contributions of large-site remediation to urban renewal, particularly in socio-economically disadvantaged areas, are well documented (e.g. References [15] and [16]). Regeneration of the many urban, abandoned former industrial sites located near transport corridors and waterways, particularly large ones, is an important tool for addressing societal challenges, such as climate change mitigation through residential and infrastructure development. Some jurisdictions have national financial incentive programs to support identification, investigation and remediation to stimulate “brownfields development”[17]. With respect to the social context of large-site remediation, this approach effectively moves remediation from problem-solving (RBLM) to opportunity development (neighbourhood improvement).

Remediation of small sites, for example former fuel retail sites that have impacted groundwater, may immediately and directly affect adjacent properties and residents over a relatively short time period. Whereas remediation of larger sites may affect local traffic, commercial activities, and adjacent residential liveability, over much longer periods.

10.2 Social indicators

While there is no universally agreed inventory of social indicators, the positions of various authorities and other authors reveals considerable overlap, and are summarized as broad categories of indicators in Table 2.

In purely social terms, the impacts of remediation projects include:

— community safety during remediation;

— nuisance during remediation (e.g. odour, noise, dust, local traffic congestion);

— ground vibrations (e.g. lorry movements; ground compaction);

— loss of amenity (e.g. footpath or road closure during remediation works);

— aesthetic impact of remediation works;

— community health and mental well-being after remediation;

— community social equity, vision and quality of life expectations.

11 Environmental dimension

11.1 General

There is no universal definition of the aspects or considerations that should be included under the environmental dimension of sustainable development, let alone remediation. Leading organizations (such as the WBCSD[18]) and recognized global standards (such as the ISO standards for environmental management[19]) include the following aspects:

— energy and climate change;

— water resources;

— ecosystem services and land use;

— raw material/resource use and pollution prevention.

Site remediation activities often have direct environmental impacts including air emissions, water consumption, non-renewable energy utilization, landfilling of waste and resource usage.

11.2 Environmental indicators

Several agencies have published lists of environmental indicators. None is comprehensive but there is considerable commonality, which allows robust site-specific indicators to be readily identified. Table 3 highlights the five core elements or aspects recommended by the US EPA for evaluating the environmental aspects of remediation projects.[20] The SuRF-UK[7],[25] has also proposed five categories of environmental indicator that should be considered in a sustainable remediation assessment (Table 2).

Table 3 — Core elements for evaluating the environmental aspects of remediation (based on Reference [20])

	Core element	Evaluate negatives	Evaluate positives
1	Energy	Total energy use: natural gas (BTU; MJ), electricity (kWh), fuel (gallons or litres)	Renewable energy applied (KWh saved by solar, wind, geothermal, biomass energy)
2	Air	Total air pollutants, GHG emissions (CO_2), dust	GHG emission reductions (CH_4 to CO_2)
3	Water	Total water use (litres)	Water recovery (litres)
4	Land and ecosystems	Total land disturbed (acres, hectares); noise and lighting disturbances	Land reuse (acres, hectares); ecosystems enhanced
5	Materials and waste	Waste generated (tons/tonnes) Use of resources (chemicals, cables and pipes, etc.)	Reduced waste generation (tons/ tonnes) Materials reused (tons/ tonnes)

12 Indicators and metrics

12.1 General

The following roles of "indicators" and "metrics" are recommended. Indicators allow comparisons between candidate remediation strategies. Metrics measure indicators. For example, if an indicator involves "use of fossil fuels", the metric may be "fossil fuel energy used in kilojoules".

It is helpful to think about indicators and metrics in terms of where they fit in the hierarchy of sustainable remediation project planning (Figure 2). The metrics for individual indicators should be collectively assessed to allow comparisons to be made about the overall relative sustainability of different remediation strategies.

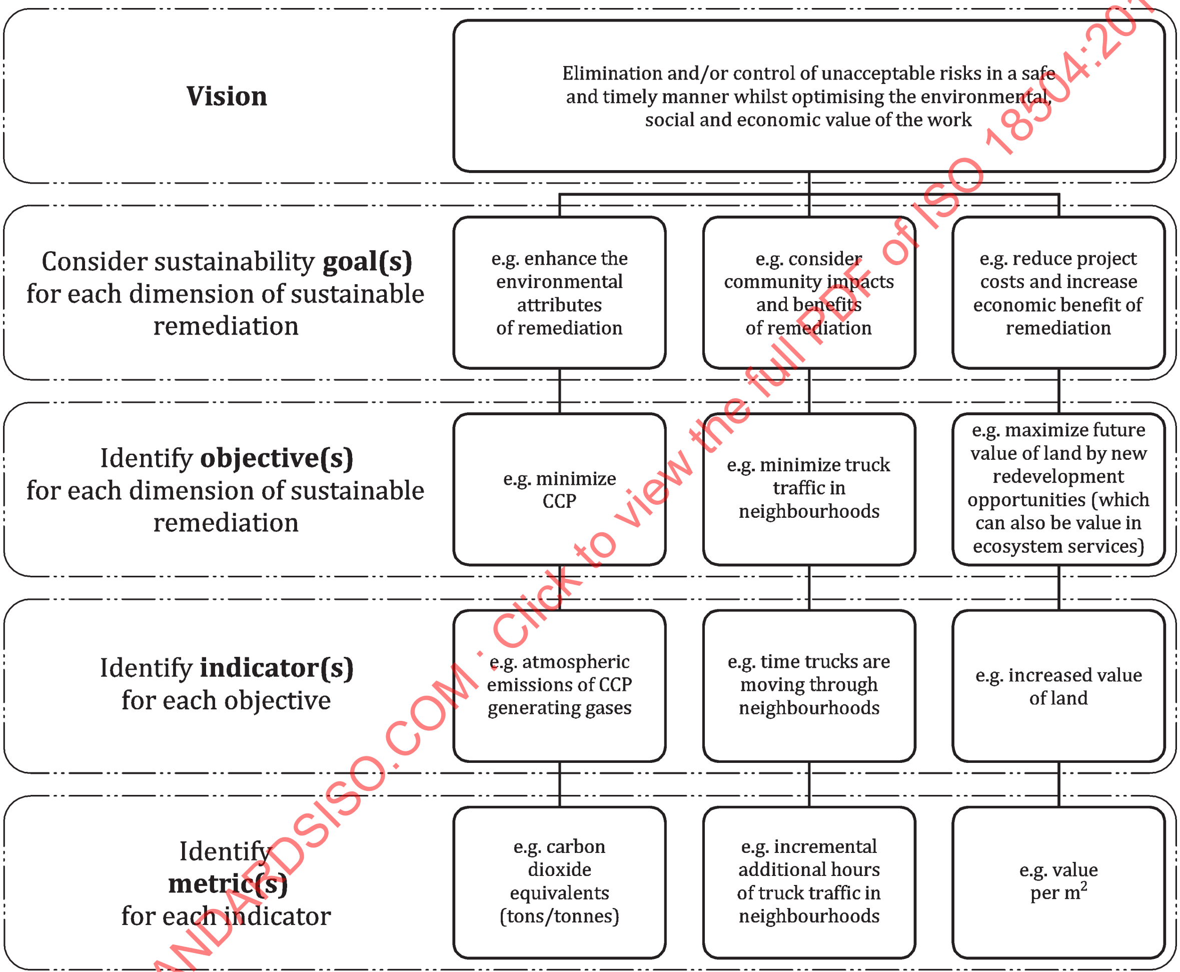

Figure 2 — Vision, goals, objectives, metrics, and indicators hierarchy for sustainable remediation – improving remediation through thinking "sustainability"

There may be multiple objectives associated with each goal. And like the project goals, the objectives may vary from project to project.

From the objectives, a single indicator is typically identified to represent the objective, and likewise, a single metric is identified to represent the indicator.

While many practitioners work to develop metrics for their project planning, it is important that they are aligned with a project's vision, goals and objectives. Because each remediation project has unique challenges, attributes, opportunities and stakeholders, it is not possible for the global remediation industry to agree on a list of indicators and metrics that are comprehensive and applicable to all projects, however broad holistic categories (Table 2) are widely used to frame sustainable remediation assessment.

Appropriate indicators and metrics may vary between different project phases. For example, the indicators and metrics used for remediation selection may be different to those utilized for remediation action operations. The former may involve evaluating indicators and metrics for the purpose of selecting the strategy that has the most number of sustainable remediation attributes, as defined by project stakeholders. As the project moves to the remediation implementation phase of the project, operations and maintenance metrics may be the focus of metric and indicator tracking. This is an example of how the project vision, goals and objectives will change throughout the lifecycle of the remediation project, and thus influence the indicators and metrics used in different phases of the project.

The remediation industry has developed numerous sets of indicators and metrics (see 12.4). Given the unique nature of each individual remediation project, the metrics that are selected for evaluating, or improving, a remediation strategy will vary depending on the perspectives of the key stakeholders.

In the course of indicator and metric identification, it is possible that practitioners may "overreach" in identifying the number of indicators and metrics that are evaluated for a specific project. There is no ideal number of indicators and metrics that "should" be considered. But practitioners should be cognizant that the greater the number of indicators and metrics, the less important they become in sustainable decision making. Some indicators and metrics may have more weight put on them, based on stakeholder preferences, and this is a reflection of the decision making priorities held by the stakeholders.

In some cases, the sustainable remediation assessment, based on site-specific indicators and metrics, may constitute the full decision-making process for a project. In other cases, it may only represent a component of the decision-making process. Practitioners should be cognizant of the relative weight of sustainable remediation indicators and metrics in the overall decision making context. In the latter case, the sustainable remediation indicators and metrics will have even less influence on project decision making, so a smaller and more focused list of indicators and metrics should be considered, as compared to decision making that only considers sustainable remediation indicators and metrics.

12.2 Setting objectives for remediation

Setting objectives for remediation is one of the types of objectives set that shall be reconsidered in a sustainable remediation assessment (see 8.4). Traditional remediation has often been linear with the principal (and sole) objective being the remediation of a site to a certain end-point. A sustainable remediation approach would be more holistic and would consider the ultimate objective as attaining risk-management goals in a sustainable manner (see Figure 3).

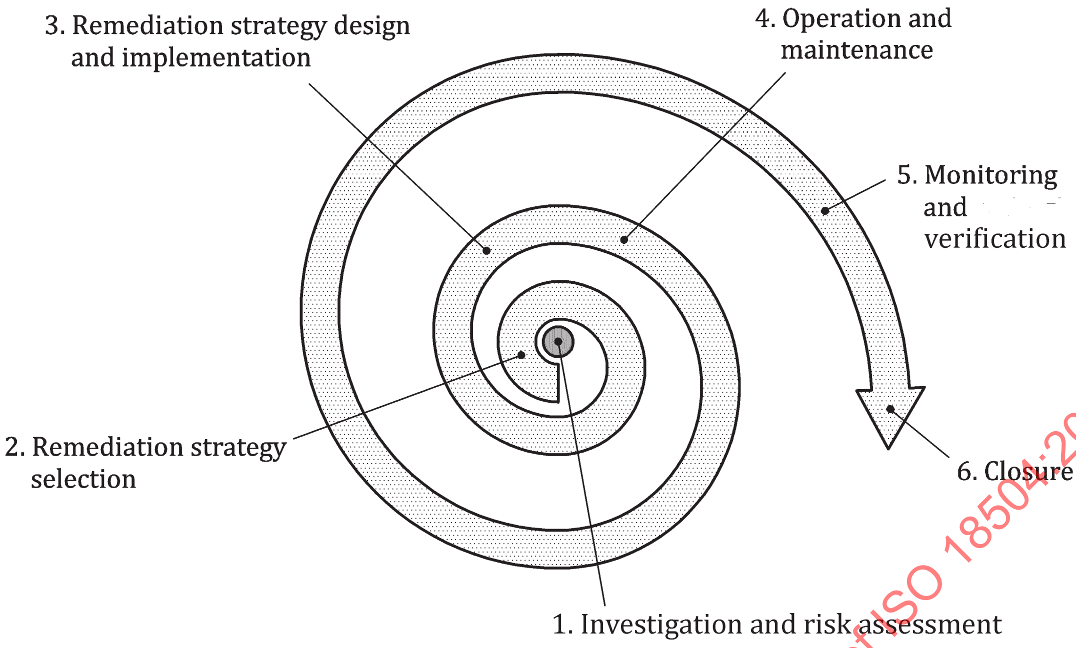

Figure 3 — Framework for sustainable remediation[4]

Traditionally, remediation practitioners have monitored contamination reduction, remediation system performance and financial expenditure. This has allowed system optimization, such as reducing maintenance requirements, ensuring adequate contaminant capture and demonstrating performance through groundwater monitoring.

As shown in Figure 3, sustainable remediation entails the integration of thinking "sustainability" throughout the remediation process. As such, remediation practitioners may consider other relevant indicators to monitor the environmental, social and economic performance. The indicators and metrics identified and used in remediation planning stage could also be used in ongoing operations. The following are examples of some data that may be obtained:

— construction project: hours of operation of machinery;

— water and energy consumption;

— number of site visits, distance travelled;

— quantities of waste generated/managed;

— materials re-used;

— contaminant quantities recovered;

— treatment system operational data: hours operation, events, flowrates, etc.;

— worker safety (e.g. lost time incidents);

— complaints received;

— locals employed.

By expanding the traditional monitoring to include sustainable remediation metrics, you may obtain better control of overall project performance. If data shows key indicators outside the predicted range, action may be taken. The compiled data may then be used to engage stakeholders, improve management, improve future planning decisions and for incorporation in corporate sustainability reporting.

12.3 Quantification and qualification

Quantitative assessments may be used when all the site-specific indicators can be quantified. The fact that an indicator cannot be measured does not reduce the importance of its consideration. If a relevant indicator cannot be quantified, then the overall assessment — based on hybrid qualitative and quantitative indicator metrics — will be qualitative.

The benefits of quantitative assessment are that the numbers are easy to understand, compare and communicate. This may result in less disagreement on the results of the assessment. Quantitative assessments are also more time intensive and expensive to complete.

Qualitative metrics are beneficial on smaller or simpler projects where a screening level sustainable remediation assessment is sufficient and where a quantitative evaluation would not provide any added value to the decision-making process. The limitation of the qualitative approach is potential poor resolution of different indicators, possible subjectivity of results, and hence of ensuing decisions. This subjectivity may be reduced by the early interaction and input from stakeholders to ensure all perspectives are considered.

Whether a quantitative, semiquantitative or qualitative approach is used, the assessors should clearly understand the limitations of the evaluation and take full account of them in any subsequent decision making. As mentioned previously, early input from all stakeholders will lessen the limitations of the assessment.

12.4 Options for indicator and metric selection

Several organizations, particularly SuRF and SuRF-UK, have developed sets of indicators and metrics for sustainable remediation assessment. Other recognized indicators include those from traditional LCA (e.g. Reference [22]). However, these indicators typically focus on environmental factors and typically do not address social or economic factors beyond human health. Other recognized indicators sets include those developed by the US EPA and US Department of Defense. These indicators sets, however, are small and very focused on addressing objectives set forth by Presidential Executive Orders of the US Department of Defense Policy.

Project specific vision, goals and objectives related to individual projects should influence the selection of sustainable remediation indicators, and their metrics.

With all the resources available for indicators, however, a "universe of indicators" may be considered to exist and is represented by all the available indicators sets. However, before selecting indicators and metrics, it is recommended that project teams follow the hierarchy identified in Figure 2. This will ensure that the best indicators and metrics selected will represent the stakeholder preferences for sustainable remediation.

13 The role of sustainable remediation assessment tools

13.1 Sustainable remediation assessment

Specific sustainable remediation assessment tools have been developed by some companies and corporations (e.g. individual consultants or site owners) or governments (e.g. Reference [23]). Generally, such tools are quantitative and limited in both the range of indicators involved and the range of remediation technologies considered. In many cases, a formal tool may not exist that allows all the indicators and metrics selected to be assessed. As such, these tools have a role to play within specific contractual or policy contexts but are less useful in most cases.

The available off-the-shelf tools are typically:

— to meet specific objectives;

— developed pre-populated with specific indicators and metrics;

— based on geographic and process specific information.

Each of these aspects is described in 13.2, 13.3 and 13.4.

Other more generic commercial tools [e.g. (LCA life cycle assessment software)] have also been used within sustainable remediation assessments. These are more complex to use and require the details of the individual alternative remediation strategies to be included.

13.2 Intended objectives addressed by tools

Each sustainable remediation assessment tools has been designed to meet that specific objectives considered important by the tool's developer or their sponsor. These objectives may not necessarily be easily translated to projects with different objectives.

For example, the SiteWise™1) tool was developed by Battelle, the US Navy, and the US Army Corp of Engineers in response to US Presidential Executive Order requirements and US Department of Defense Policy. As such, the indicators and metrics in SiteWise™1) are uniquely suited to making decisions for US Department of Defense sites but may be inadequate for the specific sustainability goals and project objectives at other sites (e.g. corporate site owners in the USA, site owners outside the USA).

13.3 Pre-determined indicators and metrics

Another consideration in using sustainable remediation assessment tools is whether the project indicators and metrics provided by the tool are defining the project indicators and metrics, or if the tool is simply being used to develop quantitative or qualitative input for several indicators already developed by the project team.

For example, when using LCA tools, practitioners may choose from a large number of impact categories to identify the categories to be used in decision making. However, if the practitioner is solely focused on using results from an LCA for decision making, it will be heavily skewed toward environmental considerations and have virtually no indicators and metrics for the social and economic aspects. LCA is certainly useful in identifying the potential environmental impacts of a project but other tools and approaches will be needed to evaluate the social and economic aspects.

Sometimes it may be easier to adopt the indicators and metrics offered within a specific tool. However, by using this approach, the practitioner needs to accept they are also accepting the goals and objectives of the organization that developed the tool, rather than unique project-specific goals and objectives.

13.4 Geographic and process specific information

Specific tools are typically pre-populated with information such as "footprint factors" or "life cycle inventory" information. This information is typically based on a specific assumption. For example, fuel efficiency for personal automobiles would be specific to the type of automobile used. So using a US tool for a project in Europe may overestimate fuel usage and combustion emissions. Energy is another example of a location-specific consideration because energy impacts vary geographically due to the different energy sources that may be utilized by the local utility.

From a process-specific consideration, it is important to understand the basis of the information being utilized to determine its applicability to a specific project. Simply using "vegetable oil" footprint factors may result in misinterpretation of the project footprint if the tool uses data for rapeseed oil and the remediation will involve soybean oil. Recent studies by US EPA have reported on the variability in results from different tools based on the different inherent assumptions used within each tool.

1) This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

