C-001, in K.A. Fields and G.B. Wickramanayake (Chairs), *Remediation of Chlorinated and Recalcitrant Compounds—2010.* Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2010). ISBN 978-0-9819730-2-9, Battelle Memorial Institute, Columbus, OH, **www.battelle.org/chlorcon**.

Sustainable Remediation: Definitions, Practices, and Controversies

Michael E. Miller (millerme@cdm.com) (CDM, Cambridge, Massachusetts, USA)
Carol B. Baker (cbaker@chevron.com) (Chevron Energy Technology Company, Richmond, California, USA)

ABSTRACT: Sustainable remediation is the conduct of remedial action with the objective of balancing conservation of natural resources and biodiversity, economic viability, and the enhancement of the quality of life in surrounding communities (the elements of the triple bottom line). Sustainable remediation is a holistic approach that is best carried through all stages of a remediation project, but can also be applied midstream to achieve benefits at any stage. In contrast, green remediation, generally favored by U.S. regulatory agencies, is the practice of considering all environmental effects of remedy implementation, and incorporating options to maximize the net environmental benefit of cleanup actions. Green remediation is a subset of sustainable remediation, with economic and social considerations not included. Regulatory agencies in the United States, mainly the U.S. Environmental Protection Agency (USEPA) and a few state agencies, have developed guidelines and policies that encourage incorporation of mostly green elements into remediation projects. A number of professional organizations are advancing sustainable remediation through compiling information, furthering research, and drafting standards for implementation. A number of processes and calculation tools are available for measuring the progress and success of sustainable remediation, with typically a combination of these methods necessary to cover all the elements of the triple bottom line. Further advancement of the field will be led by site demonstration projects, collaboration among regulatory agencies with concurrent migration from green to sustainable approaches, new multidisciplinary university programs, and continued development of applicable tools and metrics.

DEFINITIONS

A widely used definition of sustainability derives from the United Nations World Commission on Environment and Development (1987), also known as the Brundtland Commission. The definition states that sustainable development “meets the needs of the present without compromising the ability of future generations to meet their own needs.” A way of achieving sustainability is to strive to attain the triple bottom line (Elkington, 1994), which is defined as balancing environmental, economic, and social interests for a project or business as a whole. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management (2007), defines sustainability as the capacity to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans.

These ideas give rise to the concept of sustainable remediation, for which a number of complementary definitions exist. The Sustainable Remediation Forum (SURF, 2009) provides this definition: “a remedy or combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources." SuRF-UK (2009) identifies sustainable remediation as "the practice of demonstrating, in terms of environmental, economic and social indicators, that an acceptable balance exists between the effects of undertaking the remediation activities and the benefits the same activities will deliver." We present here a comprehensive definition, motivated by the SURF (United States) Web site http://www.sustainableremediation.org/about/, whose elements guide its application: conduct of remedial action with the objective of balancing conservation of natural resources and biodiversity, economic viability, and the enhancement of the quality of life in surrounding communities. These principles apply to individual remediation processes and the entire project life-cycle, from the initial planning stages, through site investigation, remediation process selection and design, remedy implementation, site close-out, and reuse (Lemaster et al., 2008). It is understood that the purpose of contaminated site remediation is to first mitigate negative effects to human health and the environment, but sustainable remediation can be a viable approach that also incorporates the balancing principles of the triple bottom line.

Sustainable remediation is most effective when it is a collaborative process, with input from diverse stakeholders, including the responsible parties, local governments, regulators, and the affected businesses and communities. In making decisions, the stakeholders recognize there can be trade-offs between different potential cleanup approaches. The balancing of environmental, economic, and social goals is the mechanism used to reach a compromise that will accommodate diverse needs and values. Environmental considerations can include reduction in carbon energy, and its accompanying greenhouse gas emissions; minimizing the consumption of chemicals, water, and other resources; protection and/or restoration of ecosystems; minimization of waste streams and recycling; and a bias towards implementing methods that destroy the contaminants of concern. Economic considerations can include life-cycle costs of the remedial options and of the project as a whole; future land use; and local community economic effects, such as job creation, business disruption during remediation, and property values. Social considerations can include identification and involvement of diverse stakeholders; collaborative decisions on future site use; minimization of traffic, noise, odor, and lighting disturbances; ethical and equity issues; and effects on both local and global communities. Sustainable remediation can be a catalyst for outreach and education, whereby sustainability practices extend beyond the scope of the project and affect general pollution reduction/prevention efforts and increase community self-sufficiency. This balancing of the triple bottom line can lead to unexpected and innovative solutions, remedial goals, and future site uses.

In contrast, green remediation as defined by the USEPA (2008) is "the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions." Green remediation is intended to reduce the overall environmental footprint of the remediation, including air pollution, water cycle imbalances, soil disruption, ecological harm, and greenhouse gas emissions. Thus, green remediation is a subset of sustainable remediation, where the environmental aspect of the triple bottom line is the only focus; economic and social considerations are not explicitly included, and their balance is not pursued. The USEPA has not embraced sustainable remediation, at least in part out of concern that its application would become an excuse for performing no remediation at all, or that monitored natural attenuation might become the only form of "active" remediation (SURF, 2009).

However, we note that these outcomes could be avoided by intelligent regulatory collaboration and oversight. Furthermore, proper application of sustainable remediation is incompatible with these feared outcomes.

HISTORY AND BACKGROUND

Sustainable remediation has evolved out of traditional remediation as a necessary step to accommodate modern needs of fuel and resource conservation and carbon emissions control. The path towards sustainable remediation began in the 1960s when the recycling industry was born and there was a slow but growing recognition that wastes that were normally discarded needed to be more permanently addressed. Waste containment was a common solution, with technologies to treat the waste under development. Two decades later, the remediation industry had matured and evolved to the point that contamination was primarily managed by engineered solutions, such as groundwater pump-and-treat, thermal desorption, vapor extraction with vapor treatment, excavation with landfilling, and capping with monitoring. The selection of remedial technologies was historically based on fundamental criteria of human health protection, technical practicability, efficacy, cost, and regulatory acceptance. Further transformation of the remediation industry began with the Brundtland Commission's 1987 definition of sustainable development, and the increasing focus on factors contributing to global climate change. Continued evolution of the remediation field saw the development of in situ treatment technologies with greater attention to contaminant destruction and recycling or reuse whenever possible. By the 2000s some practitioners began to consider the local and global environmental effects of the remediation project, as well as its economic and social effects. The formal recognition of this triple bottom line approach to contaminant cleanup could be considered the origin of sustainable remediation.

Regulatory Agencies in the United States. In the United States, there are currently no regulatory requirements to include sustainable principles in the site remediation process. However, the USEPA and a few states have developed green (not sustainable, with the exception of Minnesota) policies that they would like site owners and operators to consider. These policies revolve around the work of the USEPA Office of Solid Waste and Emergency Response (OSWER) starting in 2008, who identified the five core elements of green remediation: energy, air, water, land and ecosystems, and materials and waste (USEPA, 2008). OSWER stated the goal of green remediation was to ensure protection of human health and the environment, while reducing the environmental footprint of cleanup activities to the maximum extent possible (USEPA, 2009a). Footprint can be defined as the broader environmental effects of an activity, such as the depletion and degradation of natural resources, or other potential consequences (USEPA Region 1, 2010). The various USEPA regional headquarters, with the exception of Regions 6 and 8 to date, have issued their own policy documents, which are consistent with and include the USEPA five core elements of green remediation. The regional policies cover various site cleanup programs and emphasize such green practices as the use of renewable energy, cleaner fuels, minimal resource use, recycling, waste and emissions minimization, etc.

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) formed a Greener Cleanups Task Force, which began the following nine initiatives to encourage greener remediation approaches: loans and grants, reduced processing time and fees for remedy documents, fee incentives for green remediation, contract incentives, publicity and recognition, consultant education and accreditation, increase brownfields credit green building programs, supplemental environmental projects, and carbon offsets and credits (ASTSWMO, 2009).

While many state agencies are watching the EPA policies and directives and deciding whether to develop their own state-specific policies, six states have forged ahead with their own programs. Many other states are in the process of evaluating and developing green or sustainable cleanup policies. The Illinois EPA (IEPA, 2007) developed a matrix to guide practitioners through required actions to achieve greener cleanups. The Wisconsin Department of Natural Resources (WDNR, 2010) developed a Sustainable Remediation Reference Guide for evaluating proposed remediation systems and providing a framework for measuring outcomes. Although they use the term sustainable, the Wisconsin guide is purely green, as it is focused on energy, greenhouse gases, waste minimization, and recycling. The Minnesota Pollution Control Agency (MPCA, 2002) has developed several guidance documents for "green sustainable remediation," which intend to mitigate risk to human health and the environment; incorporate community goals; and consider social, economic, and environmental issues. The California Department of Toxic Substance Control (DTSC, 2007) encourages the use of green technologies to restore contaminated sites, spanning the entire life-cycle of the remediation project. The Alabama Department of Environmental Management (ADEM) encourages, but does not mandate, the incorporation of green practices to reduce waste and promote conservation during the remedial process. ADEM evaluates the effectiveness and success of such remediation projects on a case-by-case basis. The New York State Department of Environmental Conservation (NYSDEC, 2010) has proposed a program policy that establishes a preference for remediating sites in the most sustainable manner, while still meeting all legal, regulatory, and program requirements. The proposed policy expresses a preference for green remedies without compromising the requirement to protect human health and the environment. The NYSDEC approach also recognizes the potential for positive economic and social benefits of site reuse, and supports coordination of site reuse and remediation.

Professional Organizations. In 2009, USEPA requested ASTM International to develop a standard for green cleanups using ASTM's standard consensus-based process. ASTM subsequently formed a task group under Subcommittee E50.04 on Corrective Action, solicited volunteers, and held an initial meeting in the fall of 2009. Many attendees felt strongly that the document should not focus solely on green cleanups, but that economic and social aspects should be included as well. The working title of the standard guide is "Green and Sustainable Site Assessment and Cleanup," and representatives from industry, consulting, and regulatory agencies are actively involved in its writing. The document has gone through a number of iterations with much controversy regarding social and economic issues that may be beyond the scope of some traditional, regulatory cleanup programs. A newly organized draft document (ASTM, in draft) advocates a three-tiered approach, which is a scalable framework to integrate, balance, and maximize the short- and long-term environmental, economic, and social aspects under various cleanup programs for more sustainable remedies. The draft includes examples, best management practices, and possible metrics.

The Interstate Technology and Regulatory Council (ITRC) formed a Green and Sustainable Remediation (GSR) team in January 2009 to develop documents focused on informing state regulators. More than 100 industry members, consultants, and state and federal regulators collaborated to write a draft document, which provides an overview of the GSR field today, provides detailed information on the triple bottom line, and proposes metrics and tools that can be used to include sustainability in remediation decision making (ITRC, 2010). The ITRC GSR work group is currently developing a second technical regulatory document. ITRC and ASTM, while different organizations with different missions, are loosely coordinating their efforts to ensure that their documents are complementary, providing neither redundant nor conflicting material.

The Sustainable Remediation Forum (SURF) in the United States is a group of industry, consultants, vendors, and regulators that started in late 2006 and incorporated as a non-profit professional organization in January 2010. The mission of SURF is to maximize the overall environmental, societal, and economic benefits from the site cleanup process by advancing the science and application of sustainable remediation, developing best practices, exchanging professional knowledge, education, and outreach. SURF members wrote a compilation of sustainable remediation information, "Sustainable Remediation White Paper – Integrating Sustainable Principles, Practices and Metrics into Remediation Projects" (SURF, 2009). The white paper describes the current status of sustainable remediation in the United States and globally, introduces sustainability concepts and practices, provides an overview of impediments and barriers, presents a sustainability vision, and suggests methods of applying sustainability principles to remediation projects. The paper concludes that "sustainability means change," and ultimately should be incorporated into the regulatory framework for site remediation. Information contained in the SURF document has been instrumental in informing the current ASTM and ITRC efforts.

Sustainable Remediation Forum UK (SuRF-UK) is a United Kingdom based steering group of key partners interested in contaminated land, which includes land owners, regulators, and consultants. In 2009 they concluded that there is a need for a comprehensive set of indicators for sustainability appraisals of remediation projects (SuRF-UK, 2009). This work led to "A Framework for Assessing the Sustainability of Soil and Groundwater Remediation" (SuRF-UK, 2010), which discusses why sustainability concerns associated with remediation should be factored in at the start of a project, identifies points in the remediation process where sustainability should be considered, and links land use design with sustainable remediation strategies.

HOW SUSTAINABLE REMEDIATION CAN BE APPLIED

Sustainable remediation is a holistic approach that is best carried through all stages of a remediation project from planning through site close-out. However, these same principles and practices can be applied to remediation projects already in progress to achieve sustainability benefits at any stage.

Implementation. The beginning of a project, when environmental concerns are first identified, is the ideal stage for incorporating sustainability as an integral component. The planning stage is the time to identify and involve stakeholders, including the local community. Initial outreach is undertaken to provide basic information and education about the site and its potential risks. The stakeholders are engaged to provide input on future land use planning; and to air their sensitivities, concerns, and goals. The stakeholders should be kept informed and involved throughout the project.

The remedial investigation phase affords opportunities for managing the environmental footprint of site activities. Example sustainable site investigation practices are described as follows (SURF, 2009): low-flow or passive groundwater sampling minimizes waste and energy; direct-push technology for sampling and well installation offers a more energy efficient and less disruptive approach than conventional drilling; field screening analytical methods minimize the number of samples requiring transport to and analysis by a laboratory, and allow efficient field decisions concerning areas that might require further investigation; geophysical methods, which can identify and map certain subsurface features, are non-intrusive, portable, very low energy, do not generate investigation derived waste (IDW), and provide preliminary data in the field.

At the feasibility study stage, sustainability considerations—environmental, economic, and social—are incorporated in the evaluation. As possible for each potential remedial technology, the practitioners quantify energy requirements, water needs, resource needs, waste generation, contaminant removal, risk reduction, worker risk, cost, etc. For factors that are not quantifiable or minimal data exist, their potentials are ranked: for example, community benefits, job creation, and improvements to property values. At this stage, trade-offs between such factors as treatment aggressiveness, risk, ecological disruption, costs, and community needs are weighed. Remedy selection will then be based upon the results of the comparative analysis, with collaborative or advisory input from the stakeholders. Weighting factors may be necessary if certain issues are considered more important or higher priority than others.

Once the remedial approach is chosen, the remedial design phase begins by evaluating remedial technologies and utilizing design tools to customize the approach to meet sustainability goals. Typically a combination of remedial technologies is used, and detailed evaluation can be performed such as by life-cycle assessment (LCA), where resource and energy use, as well as emissions and waste streams throughout the project lifetime are quantified. The LCA process identifies critical parameters, and potential effects on human health, environment, economies, and communities, thereby leading to opportunities to improve the sustainability of the remedial design. Furthermore, the sustainable design process encourages incorporation of renewable energy to power equipment, water reuse, and recycling of waste streams wherever possible.

During construction, sustainability opportunities for heavy equipment include minimizing its usage, employing renewable fuels (biodiesel), and operating procedures that specifically limit idling time. Waste generation is minimized, and that which is created is segregated and reused or recycled as possible. The construction work is planned to minimize disruption of the local community by traffic to and from the site, noise, odors, and excess lighting. Also, any building construction, such as to house equipment, can make use of high performance building principles, as in Leadership in Energy and Environmental Design (LEED®) standards. Most of these construction considerations can be expected to increase the project efficiency, and thus decrease costs as well.

Operation and maintenance of the sustainable remediation systems will make use of performance data to periodically optimize the treatment processes. As remedial goals are approached, the treatment intensity may be decreased and/or other remediation technologies more appropriate to lower concentrations may be applied. Also as appropriate, sustainable sampling and analysis can be used as described above for the remedial investigation phase.

Measurement. A number of processes and calculation tools are available for measuring the progress and success of sustainable remediation projects. A few of the more comprehensive measurement methods are described here, but even so, a combination of these methods is necessary to cover all the elements of the triple bottom line.

LCA is a systematic modeling process, focused largely on the environmental aspect, that captures resource use, energy use, and emissions (to soil, water, and air) throughout the entire life-cycle of a product, service, or process; recognizing the interdependence and interconnections of all stages throughout the system. The International Organization for Standardization has promulgated the ISO 14040 series of standards for performing an LCA, which follows four main phases: (1) Goal and scope definition describes the intended application and the reason for carrying out the study, and indentifies a functional unit and system boundaries; (2) Inventory analysis collects and quantifies input/output data for the system being studied based on the goal and scope; (3) Impact assessment looks to further understand and evaluate the potential impacts and their significance throughout the life cycle; and (4) Interpretation of results leads to conclusions and recommendations. Depending on the scope selected in step 1, the remediation project life-cycle might include raw materials extraction and processing; intermediate materials production and consumption; onsite processes and activities; and end-of-life management, including reuse, recycling, and disposal (SURF, 2009). An LCA is quite complex, and is typically carried out by one of a number of currently available software packages, which contain or provide access to very large databases that include a diverse variety of materials and processes. As yet the LCA methodology has not been widely used in remediation, so this application is under active development.

Life-cycle cost analysis (LCCA) is purely financial, and evaluates the total cost of ownership over the life of an asset or system. It is also defined as an economic model of a product or process life span from beginning to end. Typical life-cycle costs include sequentially: acquisition, installation, operation, maintenance, refurbishment, and disposal or recycling. LCCA is a widely used and accepted methodology.

The United Nations Environment Programme (UNEP) has published social and socio-economic life-cycle assessment (S-LCA) guidelines that complement environmental and financial LCAs, contributing to the full assessment of goods and services within the context of sustainable development (UNEP, 2009). The UNEP guidelines were written specifically for products, and cover production, consumption, and disposal and/or recycling. Social impacts are evaluated for workers, local communities, consumers, the larger society, and value chain actors, which are those taking part in the sequential activities that add value to the product. In order to apply S-LCA, product or project specific data must be collected by interviewing stakeholders, visiting communities, and visiting workplaces. Although the data are largely subjective and thus semi-quantitative, they are the most appropriate information to use; bypassing the subjective data would add considerable uncertainty to the evaluation. S-LCA is the least developed of the LCA disciplines, with much research activity currently underway.

Besides various types of LCA, other more specific measurement approaches that are more limited in scope can be applied. These can include carbon and water footprint analyses, energy consumption, the value of economic opportunities, and changes to property values. Worker and community health and safety risks can also be quantified, with input from insurance industry actuarial data. Various industries, remediation companies, and governmental organizations have each developed their own sustainable remediation measurement tools that combine a number of factors, but are typically focused on environmental impacts and sometimes include health and safety risk. A descriptive list of these combination tools can be found in chapter 3 of the SURF white paper (SURF, 2009).

THE FUTURE OF SUSTAINABLE REMEDIATION

Consistent application of sustainable practices, to balance environmental, economic, and social concerns, is the future of site remediation. The global forces of population growth, resource depletion, and increasing carbon emissions among others will drive remediation and other industries forward along the path to sustainability. Here we suggest a few creative collaborations and initiatives to help advance the field.

Regulators along with industry and consulting practitioners could collaborate on sustainable remediation demonstration projects, with the goal of achieving cleanup endpoints simultaneously with the balancing all three elements of the triple bottom line. These pilot projects will establish credible precedent, and evaluate approaches, tools, and metrics for conducting sustainable remediation. Regulatory agencies should work together to develop common guidelines for implementing sustainable remediation, not just greener policy, an initiative that could be facilitated by ITRC and ASTSWMO. New or modified regulations could be the ultimate outcome. Protection of the environment would remain an immutable priority, and the potential for misuse would be avoided by listing unacceptable practices and outcomes directly within the policy documents and regulations. Universities and research institutions could create multidisciplinary sustainable remediation programs, for both teaching and research, to carry the discipline well into the future. Further research and development of LCA specifically applied to remediation projects is still needed, as is the advancement of other applicable tools and metrics. Assessment of the social aspect is largely qualitative, which presents a barrier to its incorporation into remediation project planning. However, the ASTM task group has invited social scientists to collaborate on their standard guide to develop and incorporate semi-quantitative methods into sustainable remediation decision making. With many advances already made and more on the horizon, the sustainable remediation movement may also serve as an example for incorporating sustainability into other businesses and industries moving forward.

REFERENCES

ASTSWMO. 2009. *Incentives for Greener Cleanups*. http://astswmo.org/files/resources/greenercleanups/GCTF_Incentives_Paper_6-25-09.pdf.

ASTM. In draft. *Standard Guide for Site Assessment and Cleanup*. Subcommittee E50.04. http://astswmo.org/files/resources/greenercleanups/GCTF_Incentives_Paper_6-25-09.pdf.

DTSC. 2007. *Green Remediation.* http://www.dtsc.ca.gov/OMF/Grn_Remediation.cfm.

Elkington, J. 1994. "Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development*.*" *California Management Review*. *36*(2): 90-100.

Executive Order 13423. 2007. *Strengthening Federal Environmental, Energy, and Transportation Management.* http://www.whitehouse.gov/omb/assets/procurement_green/eo13423_instructions.pdf

IEPA. 2007. *Greener Cleanups.* http://www.epa.state.il.us/land/greener-cleanups/ index.html.

ITRC. 2010. In draft. *Technical and Regulatory Overview, Green and Sustainable Remediation: State of the Science and Practice Version 1a.*

Lemaster, K.M., M.E. Miller, and P.C. Reed. 2008. "Planning Tools for the Integration of Sustainability into Remediation Projects." *Proceedings of the Sixth International Conference on Remediation of Chlorinated and Recalcitrant Compounds.* Battelle Press, Columbus, OH (CD format).

MPCA. 2002. *Greener Practices for Business, Site Development and Site Cleanups: A Toolkit.* http://www.pca.state.mn.us/programs/p2-s/toolkit/index.html.

NYSDEC. 2010. *Proposed Program Policy DER-31 / Green Remediation.* http://www.dec.ny.gov/docs/remediation_hudson_pdf/der31.pdf.

SURF. 2009. "Sustainable Remediation White Paper—Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects." *Remediation. 19*(3).

SuRF-UK. 2009. *A Review of Published Sustainability Indicator Sets: How applicable are they to contaminated land remediation indicator-set development?* Contaminated Land: Applications in Real Environments, London, UK.

SuRF-UK. 2010. *A Framework for Assessing the Sustainability of Soil and Groundwater Remediation*. Contaminated Land: Applications in Real Environments, London, UK.

UNEP. 2009. *Guidelines for Social Life Cycle Assessment of Products.* http://www.estis.net/sites/lcinit/.

USEPA. 2008. *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites.* EPA 542-R-08-002.

USEPA. 2009a. *Principles for Greener Cleanups.* http://www.epa.gov/oswer/greencleanups/principles.html.

USEPA. 2009b. *Superfund Green Remediation Strategy Public Review Version.* http://www.epa.gov/superfund/greenremediation/sf-gr-strategy.pdf.

USEPA. 2010. *Green Cleanup Standard Initiative*. http://www.clu-in.org/greenremediation/docs/GCS%20Proj%20Update%20Sep%2009.pdf.

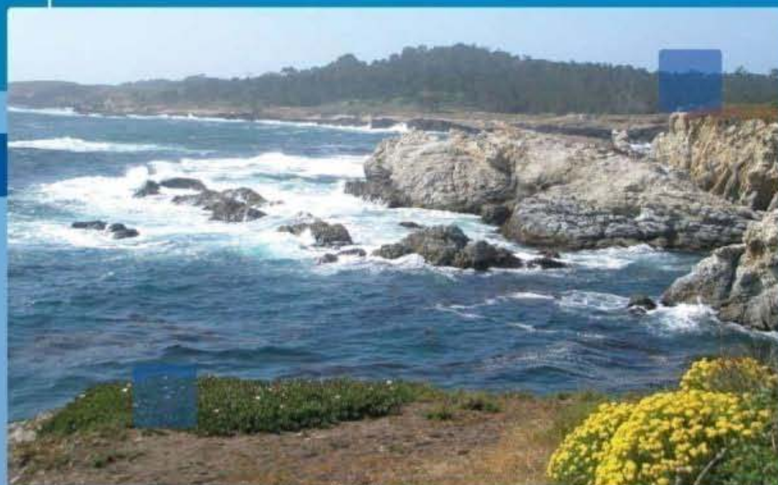
USEPA Region 1. 2010. *Clean and Green Policy for Contaminated Sites.* http://cluin.org/greenremediation/docs/R1GRPolicy.pdf.

WDNR. 2010. *Wisconsin's Initiative for Sustainable Cleanups.* http://www.dnr.state.wi.us/Org/aw/rr/cleanup/wisc.htm.

World Commission on Environment and Development. 1987. *Our Common Future.* Oxford University Press, New York, NY.

Sustainable Remediation: Definitions, Practices, and Controversies

Michael E. Miller, CDM and Carol B. Baker, Chevron



Outline: Sustainable Remediation

- What is it ???
- Where did it come from?
- What are U.S. regulatory agencies doing?
- How are professional organizations advancing the field?
- How do you apply it?
- What's next?

Sustainability: Definitions

- Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs." -*Brundtland Commission, 1987*

- Achieve sustainability through attaining the *triple bottom line* by balancing environmental, economic, and social interests for a project or business. -*Elkington, 1994*

- **It's all about Balance.**

Triple Bottom Line – TBL

Sustainable Remediation: Definition

- Conduct of remedial action with the objective of balancing conservation of natural resources and biodiversity, economic viability, and the enhancement of the quality of life in surrounding communities.

Collaborative Process

- Input from diverse stakeholders
  - Responsible parties
  - Local governments
  - Regulators
  - Businesses
  - Communities
- Trade-offs within TBL to achieve a balance
- Compromises
- Innovative solutions result

Environmental

CDM

- Carbon energy and greenhouse gases ↓
- Chemical, water, resource consumption ↓
- Protect / restore ecosystems
- Minimize waste
- Recycle
- Bias towards contaminant destruction

Economic

- Life cycle costs of the remediation
- Future land use
- Job creation
- Business disruption
- Property values
- Tax generation

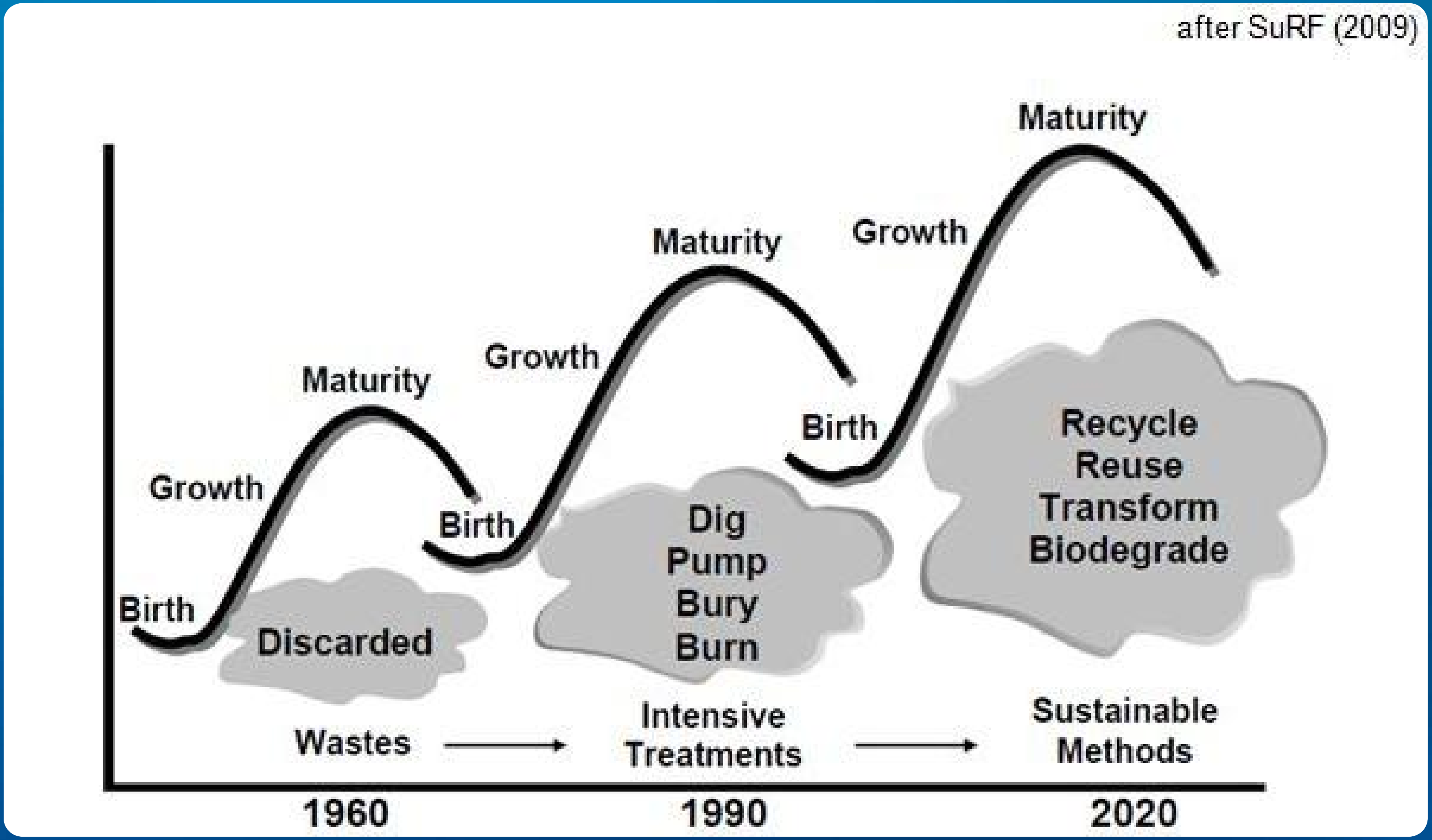
Social

- Stakeholder involvement and collaboration
- Traffic, noise, odor, lighting disturbance ↓
- Ethical and equity issues
- Effects on local and global communities
- Outreach and education beyond project

Green Remediation

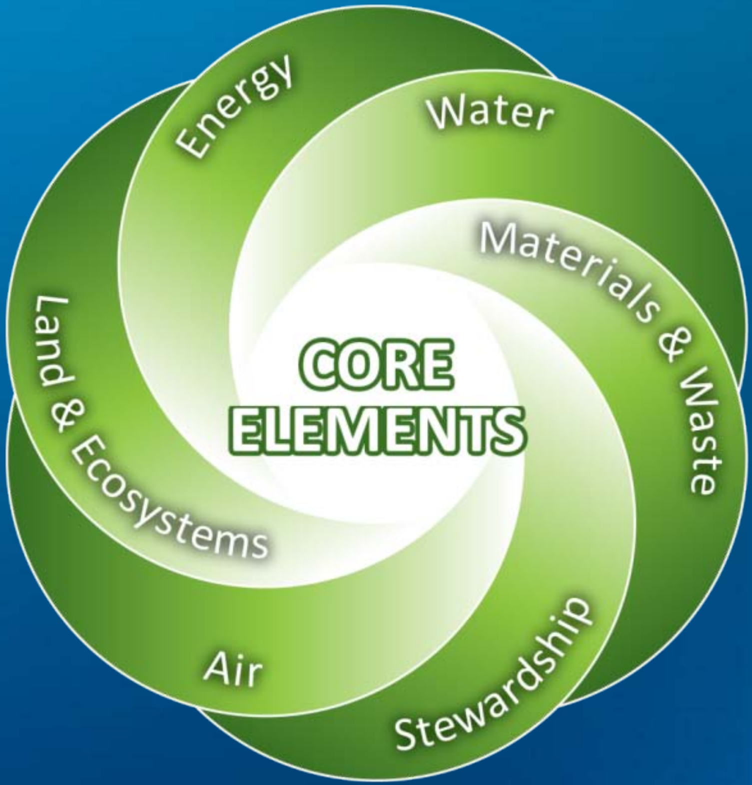
- USEPA, 2008: "the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions."
- Reduce environmental footprint of remediation
- Subset of sustainable remediation
  - *Environmental only*
- Why not sustainable?
  - Concern over potential misuse

History
The Path Towards Sustainable Remediation



US Regulatory Agencies: USEPA

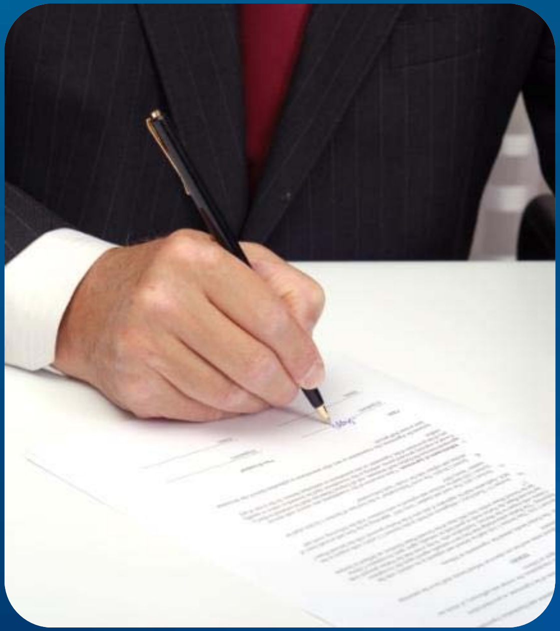
- **Green only remediation** – no TBL
- Global climate change concerns
- Core elements (USEPA OSWER, 2008):



- Most USEPA regions also have green remediation policies

States: ASTSWMO Greener Remediation Initiatives

- Association of State and Territorial Solid Waste Management Officials
  - Loans, grants, credits, contract incentives
  - Reduced document processing time
  - Publicity and education
  - Supplemental environmental projects
  - Carbon offsets



State Regulatory Agencies

Agency	Policy / Guide
Illinois EPA	Greener matrix guide
Wisconsin DNR	Green reference guide
California DTSC	Encourages green technologies
Alabama DEM	Encourages green practices
New York State DEC	Preference for green remedies
Minnesota PCA	Guidance for “green *sustainable*” remediation

Professional Organizations

- **ASTM** standard guide, under development
  - "Green and Sustainable Site Assessment and Cleanup"
- **ITRC**: documents to inform state regulators
  - GSR overview (2009), regulatory guidance in process
- **SURF-US**
  - White Paper: state of the technology (2009)
  - Ongoing development, education, & outreach
- **SuRF-UK**
  - Framework to assess sustainability of remediation (2010)

Application

- Holistic: applies to all phases
- Also apply to projects in progress
  - Retrofit, to realize benefits at any stage

Implementation - 1

- Planning and scoping
  - Engage stakeholders
- Remedial investigation
  - Field screening methods
  - Minimally invasive sampling
- Feasibility study / remedy selection
  - Balance TBL
  - Weighting factors

Implementation - 2

- Remedial design
  - Detailed sustainability evaluation
  - Minimize environmental footprint
  - Balance TBL

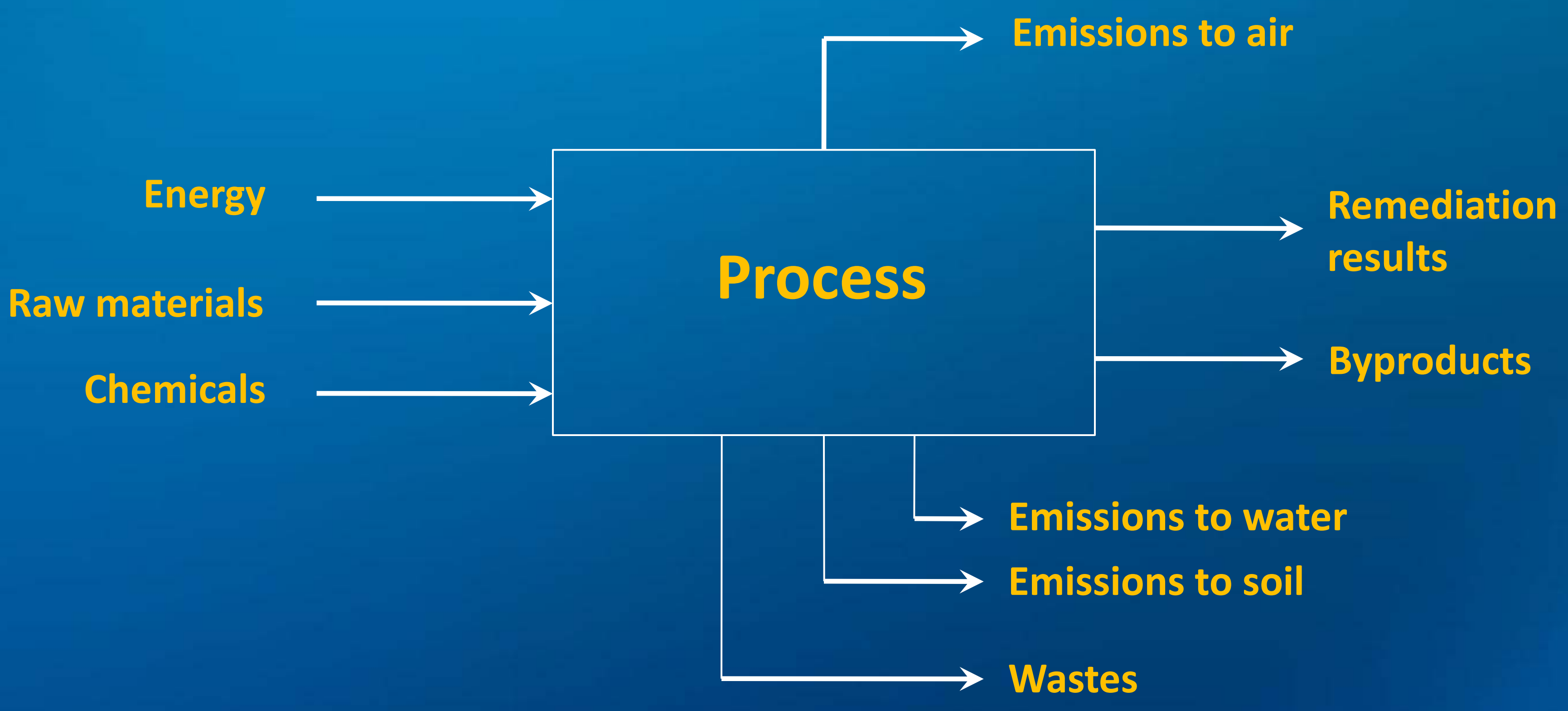
- Construction
  - Minimize heavy equipment impacts
  - Minimize waste and recycle
  - LEED® building standards

Implementation - 3

- Operation and maintenance
  - Continuous optimization
  - Low energy / low impact sampling and analysis
  - Communication: stakeholders

Measurement: Life-Cycle Assessment (LCA)

- ISO 14040 series of standards



Measurement - 2

- Life-cycle cost analysis (LCCA)
- Social and socio-economic LCA
  - Local and global
  - Semi-quantitative
  - Current research
- Several other tools
  - Mostly environmental
  - Some include health and safety risks

The Future

Future of Remediation = Sustainability

The path…

- Pilot demonstration projects
- Agencies collaborate → common guidelines / regulations
  - From green to sustainable
- Multidisciplinary research programs
- Include social and economic experts
- Balance is key