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MANAGEMENT OF SUSTAINABLE DEVELOPMENT IN RURAL AREAS:

AT LOCAL AND REGIONAL SCALES

SCIENTIFIC EDITORS
Piotr Bórawski
Ireneusz Żuchowski
Elżbieta Jadwiga Szymańska

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ul. Kołobrzeska 15
07 – 410 Ostrołęka
Tel./ fax 29 7691034
www.wses.edu.pl
e-mail: wses@wses.edu.pl

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CHANGING GRAVITY FROM ECOLOGICAL EVALUATION TO SOCIAL APPROACH IN THE SITE REMEDIATION ASSESSMENT

Ivan Forafonov
Orel State Agrarian University, Russia
Mariusz Maciejczak
Warsaw University of Life Sciences – SGGW, Poland

Abstract: The paper seeks to assess the applicability of different methodologies used to evaluate soil remediation technologies and projects. Remediation technologies are used to clean up contaminated soil (sites). It argues that while current literature and projects target internal ecological aspects of remediation, it is already possible to foster the transition from traditional ecological evaluation to include also measuring social impacts of site contamination and remediation. Such evolution in the approach frames a more cohesive foundation for assessing and implementing remediation technologies based on an array of socially relevant data, as opposed to narrow quantification of ecological properties of a remediated site.

Key words: site remediation, contaminated sites, ecological evaluation, cost-benefit analysis, risk-based assessment, sustainable remediation, social dimension.

12.1. Introduction

As a result of technogenesis, more soils are becoming disturbed and contaminated, subsequently, soil contamination pose risk to public health and environment. Land mismanagement has a negative influence on the soil ecosystems with unsustainable development contributing to soil contamination. In order to clean up contaminated soils and make them suitable for further use, various remediation methods are applied to remove contaminants from soils[1].

Soil remediation is a complex process that involves not only some contaminant removal procedure but also selection of remediation technology, effectiveness assessment and introduction of innovations. The algorithms for selecting site remediation technologies were established more than 40 years ago[2]. Since then, a large number of successful projects were carried out and a great amount of research has been conducted on developing

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[1] A. S. Goudie, [2009]: *The Human Impact on the Natural Environment*: *Past, Present, and Future. Science. 2/2009.*

[2] U.S. Sustainable Remediation Forum., [2009]: *Sustainable remediation white paper—Integrating sustainable principles, practices, and metrics into remediation projects. Remediation, no. 19, pp. 5–114. doi: 10.1002/rem.20210.*

new remediation technologies and improving policy – and decision-making systems, with appropriate legislation adopted in the spheres of environmental protection and remediation (e.g., Cauwenbergh[3]).

Yet, there are fewer studies on summarizing and generalizing the results of the remediation practices as a whole[4]. Methods of selecting remediation technologies rely mainly on most evident indicators of the technology performance, i.e. the percentage of contaminant removed or otherwise treated contaminants and enhancement of soil physical, chemical and biological properties. This approach to evaluating remediation projects was omnipresent when the remediation industry originated, but over time more comprehensive quantitative and qualitative tools which evaluate remediation technologies were created.

The Environmental Agency of the United Kingdom was among the first to develop an extensive guideline for cost-benefit analysis in site remediation[5]. The cost-benefit analysis compares possible choice of remediation technology by monetizing the damage avoided. Another tool for measuring remediation effectiveness is risk-based assessment which is used around the globe as a methodology to evaluate the exposure for people's health and environment caused by site contamination[6]. A more integral tool for evaluation is life-cycle assessment (LCA), a method used to benchmark the current remediation systems, compare remediation options and identify ways to diminish possible impacts[7].

In recent years, however, practitioners and policy-makers have commenced to embody principles of sustainability into remediation projects and policies. The interest towards sustainable remediation resulted in numerous methodologies for sustainability assessment methodologies and projects that successfully implement sustainable remediation technologies[8].. Furthermore, while the idea of sustainable remediation has been already commonly accepted and became a part of governments remediation programs (i.e. US EPA[9]), various types of assessing the social dimension in sustainable remediation are coming forward as an instrument for evaluating remediation programs and technologies[10]. This should be considered as a meaningful manifestation of the shift in the evaluation paradigm from quantitative ecological measurements to a broader approach, which defines remediation from the perspective of its impact on local communities and society in general.

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[3] L. Cauwenbergh Van, [1997]: *Technology Overview Report. Ground-Water Remediation Technologies Analysis Center, Leiden.*

[4] E. Khan, T. H. Hejazi, [2004]: *An overview and analysis of site remediation technologies Journal of Environmental Management, no. 71, pp. 95-122.*

[5] M. Postle, T. Fenn, A. Grosso, J. Steeds,[1999]: *Cost-Benefit Analysis for Remediation of Land Contamination. R&D Technical Report. Risk and Policy Analysis Limited, Environmental Agency.*

[6] A. Fujinaga, M. Yoneda, M. Ikegami, [2012]: *Methodology for Setting Risk-Based Concentrations of Contaminants in Soil and Groundwater and Application to a Model Contaminated Site. Risk Analysis, no. 32: pp. 122–137. doi:10.1111/j.1539-6924.2011.01677.x*

[7] P. Suer, S. Nilsson-Paledal, J. Norrman, [2004]: *LCA for site remediation: A literature review. Soil & Sediment Contamination, no. 13, pp. 415–425.*

[8] P. B. Butler, L. Larsen-Hallock, R. Lewis, C. Glenn, R. Armstead, [2011]: *Metrics for integrating sustainability evaluations into remediation projects. Remediation, 21(3), pp. 81–87.*

[9] US. EPA., [2008]: *Green remediation: Incorporating sustainable environmental practices into remediation of contaminated sites. Office of Solid Waste and Emergency Response, EPA 542-R-08-002. Retrieved from http://www.brownfieldstsc.org/pdfs/ green-remediation-primer.pdf. Access: 12.02.2016*

[10] M. A. Harclerode, P. Lal, M. E. Miller, [2015]: *Quantifying global impacts to society from the consumption of natural resources during environmental remediation activities. Journal of Industrial Ecology, Special Issue: Linking Local Consumption to Global Impacts.*

Alongside with the seemingly evidential transmission from ecological evaluation to social approach, many scholars still use ecological evaluation as the only method to measure the results of a remediation technology. There is no doubt that ecological evaluation is the primary mechanism to quantitatively assess remediation effectiveness; in addition to that, different site-specific properties amplified by various external factors (e.g., regional and national remediation policies, stakeholder collaboration) encumber remediation evaluation. Nevertheless, it is necessary to evaluate remediation not as segregated procedure, but as an element of a multifaceted system, which implies using more extensive evaluation tools. Remediation scholars and practitioners should take into consideration sustainability principles and practices with a particular attention to the social dimension as a pivotal component in implementing advanced and sustainable remediation technologies.

The social shift is also justified in the policy re-orientation, that to a larger extent involves society, not only as a beneficiary of programmed actions, but also a co-creator of the innovation based development. This approach is observed in the network models of mutual influence of various socio-economic spheres in the economic system, ie. helix models, especially the triple and quadruple helix[11]. In 1995 Etzkowitz and Leydesdorff introduced the triple helix model for determining the dynamics of the relationship between science, industry and administration[12]. These three dynamics are considered stable. Such institutional configuration in the knowledge innovation system can also be considered as an expression of three functionally linked sub-dynamics of competing systems: the dynamics of economic wealth generation through the exchange, based on knowledge and innovation dynamics of reconstruction and political and managerial need and concern for normative control over the links. The success of these three functions should not be treated as individual relationships between industry, science and administration. According to Leydesdorff and Etzkowitz, the triple helix is a model of innovation in which the potential of cooperation determines the relationship between the three parties, and the lack of these ties significantly impedes the flow of knowledge[13] In the opinion of Carayannis, Barth and Campbell, the concept of the triple helix is associated with the concept of knowledge-based economy due to the emphasis on knowledge and innovation[14]. The triple helix model takes into account the paradigm of innovation, which as a condition sine qua non, determines the size of the pro-innovation relationship formed at the interface of science, business and administration. It is essential that such a policy orientation of cooperation creates demand among consumers, and is simply not limited to the organization of supply of already developed innovative solutions[15]. Eriksson et al. also argue that the innovation-oriented user's role is as important as the role of research institutions, support organizations and

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[11] M. Maciejczak, [2012]: *Zastosowanie modelu potrójnej heliksy w rozwoju innowacyjności polskiego rolnictwa i obszarów wiejskich. Wieś Jutra, no 11–12, pp. 24-27.*

[12] H. Etzkowitz, L. Leydesdorff, [1995]: *The Triple Helix – University – Industry – Government Relations: A Laboratory for Knowledge Based Economic Development, EASST Review no. 14, pp. 78-97.*

[13] L. Leydesdorff, H. Etzkowitz, [2001]: *The Transformation Of University-industry-government Relations, Electronic-Journal of Sociology. Retrived from http://www.sociology.org/archive.html. Access: 12.02.2016.*

[14] E. Carayannis, T. Barth, D. Campbell, [2012]: *The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship 1/2012, doi:10.1186/2192-5372-1-2.*

[15] M. Maciejczak, [2015]: *How to analyze bioeconomy?, Annals of Polish Association of Agricultural Economists and Agribusiness, vol. XVI, issue 6.*

government companies[16]. Thus the quadruple helix model describes the new economic environment and observes how society is involved in continuous innovation, which is the result of co-creation between the four helices connected through networks, partnerships and symbiotic relationships.

Without including extensive evaluation tools, the effectiveness of the remediation technology becomes disputable, as the absence of data about the social-economic impacts holds up technology implementation. Moreover, the introduction of innovation occurs due to inconsistent information about the performance of existing technologies. One of the barriers in including advanced evaluation tools is "resistance to change", which leaves practitioners with approaches that are "well worn…over the last 30 years"[17]. This can be caused by three main group of factors: technological, social, and market.

12.2.Methods and Objectives

In this study, the authors seek to provide remediation scholars and practitioners with an overview of methods used to evaluate remediation technologies and projects. A significant part of the site remediation literature utilizes an ecological evaluation and to a much lesser extent includes long-term socio-economic assessment. The US Interstate Technology & Regulatory Council revealed the issue, noting that "remedial activities often focus on site-specific risks that were not developed in consideration of external social and economic impacts beyond identified environmental impacts, in order to protect human health and the environment"[18].

The objectives of the paper, besides to indicate the current predilection towards omitting comprehensive evaluation tools, are to examine the most widespread evaluation methodologies and their variations and to illustrate the importance of transition from ecological evaluation to social dimension methodologies. Such evolution in approach frames a more cohesive foundation for assessing and implementing remediation technologies based on an array of socially relevant data, as opposed to narrow quantification of ecological properties of a remediated site.

The information presented in the article is based on an extensive and critical literature review.

12.3. Ecological Evaluation

As it was noted by Yeung, it is a formidable task to give an overview of so many proven and emerging remediation technologies[19]. In effect, many technologies and their variations have been field-tested and are used by practitioners around the world. Since most remediation technologies are site-specific, the selection of appropriate technologies

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[16] M. Eriksson, V-P. Niitamo, S. Kulkki, K. A. Hribernik, [2006]: *Living labs as a multi-contextual R&D methodology. Proceedings of 12th International Conference on Current Enterprising, ICE 2006, Milan, Italy, June 26-28, 2006.*

[17] SURF., [2009]: *Sustainable remediation white paper—Integrating sustainable principles, practices, and metrics into remediation projects. London.*

[18] ITRC, Interstate Technology & Regulatory Council., [2011a]: *Technical/regulatory guidance—Green and sustainable remediation: A practical framework. Green and Sustainable Remediation Team. Washington DC.*

[19] A. T. Yeung, [2010]: *Remediation Technologies for Contaminated Sites. (in) Yunmin Ch., Liangtong Z. and Xiaowu T. (eds.) Advances in Environmental Geotechnics, Springer Berlin Heidelberg, pp. 328-369.*

is often a difficult step for the successful remediation of a contaminated sit. Therefore, the successful treatment of a contaminated site depends on proper selection, design, and adjustment of the remediation technology's operations based on the properties of the contaminants and soils and on the performance of the system.

Table 1. **Description of selected remediation technologies**

Remediation technology	Description
Encapsulation	Physical disconnection of contaminated components from unpolluted outer medium
Biological remediation	Using biological agents such as bacteria to process or immobilize contaminants
Phytoremediation	Using plants to immobilize, process or remove contaminants
Vitrification	Using extreme temperatures to immobilize inorganic and destroy organic pollutants
Nanoremediation	Using nanoparticltes to accelerate remediation process
Bioventing	Injecting air to maximize biodegradation and minimize the off-gassing of volatilized contaminants to the atmosphere
Biopiles	Piling petroleum-contaminated soils into heaps and then simulating aerobic microbial activity by aeration and the addition of minerals, nutrients, and moisture
Soil washing	Using liquids (usually water, occasionally combined with solvents) to mechanically processes to scrub soils.
Aeration	Evaporating the volatile contaminants of from the soil into the air

Source: own elaboration based on Khan and Hejazi, 2004

All of the technologies mentioned in table 1, as well as many of those that were not included into the list, have proved to be effective and efficient. The most straightforward procedure for remediation technology selection consists of the following parameters:

1. Type of soil;
2. Type of contaminants;
3. Sources of contamination;
4. Time required to remediate.

Since the algorithm is contamination-oriented, the simplest way to measure remediation effectiveness is to calculate the percentage of removed (immobilized, processed, etc.) contaminants over time[20]. Aside from the percentage of treated contaminants over time, a number of soil properties, known as Soil Quality Indicators, are included in soil evaluation. In a recent study, as many as forty-eight Soil Quality Indicators from soil structure to root elongation are recommended for a comprehensive ecological evaluation [21].

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[20] O. K. Merkx, J. P. G. Loch, A. T. Lima, [2013]: *The Effectiveness of Electro-Remediation of Aged, Metal-Contaminated Sediment in Relation to Sequential Extraction of Metals. Water, Air, & Soil Pollution, , Volume 224, Number 9, p. 11-19.*

[21] Y. Volchko, J. Norrman, L. Rosén, [2014]: *A minimum data set for evaluating the ecological soil functions in remediation projects (2014) , no. 14, pp. 1850–1860. DOI 10.1007/s11368-014-0939-8.*

This approach, commonly known as *ecological evaluation* or *environmental risk-assessment,* does facilitate assessment of the results, although it marginalizes impact on the environment as the effectiveness measurement from a number of factors affecting remediation process as a whole. Nonetheless, ecological evaluation is the milestone and the first step in soil remediation assessment[22][23].

12.4. Risk-Based Assessment

Risk-based assessment is a method to evaluate not merely the presence of contamination, but the risks this contamination pose to public health and environment[24,25]. Different types of risk exposure are taken into consideration while conducting risk-based assessment. For example, if a remediated site is planned to be used as a residential area, the risks for contaminant transmission via evaporation or drinking water need to be assessed. A different scenario occurs if the remediated site is designed for further agricultural use, hence contaminants can permeate into food chains and contaminated products could reach consumers.

For conducting a risk-based assessment of a remediation site, according to Catney et al. a receptor exposed to a contaminant source by means of a pathway" should be confirmed[26]. Measuring concentration of contaminants is not sufficient to evaluate the risks that contamination poses to people and the environment. It is necessary to examine availability of contaminants in soil environment. Thus, the risk-assessment methodology comprises the routes by which people and the environment are affected and the availability and transportation potential of soil contaminants[27].[28] [29].

A reverse risk assessment tool specific to a contaminated site is known as remediation risk management. This tool is a risk-based decision-support system that focuses on the risks posed *to* a remediation project, not *by* it. The elements of remediation risk management are risk identification, evaluation, mitigation, monitoring and reporting.

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[22] A. Beames, S. Broekx, R. Heijungs, R. Lookman, K. Boonen, Y. Geert van, K. Dendoncker, P. Seuntjes, [2015]: *Accounting for land-use efficiency and temporal variations between brown field remediation alternatives in life-cycle assessment, Journal of Cleaner Production, 1/2015, pp. 101-109.*

[23] D. E. Ellis, P. W. Hadley, [2009]: *Sustainable remediation white paper—Integrating sustainable principles, practices, and metrics into remediation projects. Remediat J no. 19, pp. 5–114.*

[24] T. O'Berg, B. Bergback, [2005]: *A review of probabilistic risk assessment of contaminated land. J Soils Sediments, no. 5, pp. 213–224.*

[25] R. Naidu, [2008]: *Bioavailability: the underlying basis for risk based land management. Chemical bioavailability in terrestrial environment. Elsevier, Amsterdam, pp 53–72.*

[26] P. Catney, J. Henneberry, J. Meadowcroft, J. R. Eiser, [2006]: *Dealing with contaminated land in the UK through 'Developmental Managerialism'. J Environ Policy Plan 8/2006, pp. 331–356.*

[27] C. P. Nathanail, N. Earl, [2001]: *Human health risk assessment: guideline values and magic numbers. Issues Environ Sci Technol., no. 16, pp. 85–102.*

[28] H. Rothstein, P. Irving,T. Walden, R. Yearsley, [2006]: *The risks of risk-based regulation: insights from the Environmental Policy Domain. Environ Int., no. 32, pp. 1056–1065.*

[29] H. Rothstein, P. Irving, T. Walden, R. Yearsley, [2006]: *The risks of risk-based regulation: insights from the Environmental Policy Domain. Environ Int., no. 32, pp. 1056–1065.*

Table 2. **Project risk input for remedation decisions**

Risk categories	Risk description
Technology performance	Selected inappropriate remedy, Inappropriate objectives, System failure
Human health	Changes to human health risk assessment, Accidents
Economic	Value of land after remediation, Environmental insurance, Cost avoidance, Public costs
Project management	Scope, Schedule, Communications
Regulatory	Changing conditions, Emerging contaminants
Environmental	Energy consumption, GHG consumption, Harm to ecosystems, Endangered species
Other	Political conditions, Social conditions

Source: *own elaboration ITRC 2011*

Scholars have been using risk-based assessment extensively during last decades[30][31][32]. However, in many cases the assessment was either carried out for short-periods of time or included only numerical models. Incorporation of more parameters such as potential site use and planning periods would provide, according to Maqsood et al.[33] a support for decisions related to pollution prevention and mitigation prioritization in terms of effective site management", or, as Huang et al.[34] argue outliers of these parameters prevent a comprehensive risk-assessment

12.5. Cost-Benefit Analysis

Cost-benefit analysis (CBA) has been used in recent years as a practical approach to evaluate soil remediation by estimating, quantifying and comparing its total costs and benefits[35]. CBA is recommended for estimating the net benefits of environmental projects, as it provides a quantitative estimation of changes in social well-being[36].. The key advantage of CBA is that it takes into account both direct and indirect benefits of remediation projects, and determines whether the benefits of soil remediation justify its costs[37].

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[30] R. Andricevic, V. Cvetkovic, [1996]: *Evaluation of risk from contaminants migrating by groundwater. Water Resour Res 32/1996, pp. 611–622.*

[31] R. Schnatter, [2000]: *Petroleum worker studies and benzene risk assessment. J Toxicol Environ Health Part A 61:433–437.*

[32] B. L. Morris, [2001]: *Practical implications of the use of groundwater protection tools in water-supply risk assessment. Water Environ Manage., no. 15, pp. 265–270.*

[33] I. Maqsood, L. Janbing, G. Huang, Y. Huang, [2005]: *Simulation-based risk assessment of contaminated sites under remediation scenarios, planning periods, and land-use patterns—a Canadian case study. Stoch Environ Res Risk Assess, no. 19, pp. 146–157, DOI 10.1007/s00477-004-0222-4.*

[34] B. Huang, D. Xiong, H. Li, [2004]: *An integrated approach to realtime environmental simulation and visualization. J Env Informatics no.3, pp. 42–50.*

[35] D. Lavee, T. Ash, G. Baniad, [2012]: *Cost-benefit analysis of soil remediation in Israeli industrial zones. Natural Resources Forum, no. 36, pp. 285–299.*

[36] US. EPA, [2011]: *Handbook on the Benefits, Costs and Impacts of Land Cleanup and Reuse. EPA-240-R-11-001. USEPA, Washington, DC.*

[37] A. M. Wezel van, R. Franken, E. Drissen; K. Versluijs, R. Berg vand der, [2008]: *Societal cost-benefit analysis for soil remediation in the Netherlands. Integrated Environmental Assessment and Management, no. 4(1), pp. 61–74*

Estimating soil remediation costs is a relatively simple task compared to estimating soil remediation benefits, since soil remediation leads to both direct and indirect benefits[38]. Direct marketable benefits are, for instance, the increase in the site's land value due to soil remediation. Indirect non-marketable benefits may include the prevention of adverse health effects, improving water quality and influence on area's future economic performance[39].. In some scenarios, benefits from site remediation are higher than the costs, while in many other cases, the benefits do not exceed the costs[40]. The common framework is to find the optimal cost-benefit balance from zero alternatives, which usually means terminating or not starting site remediation, to the alternatives which include the estimated number of confirmed and potentially contaminated site. A discount rate is added to calculate the prospective costs and benefits at the present-day equivalent. Table 3 shows an example of CBA for soil remediation in the Netherlands with a time-span of one hundred years and a discount rate of 4%.

Table 3. Costs, benefits and balance per alternative, at a discount rate of 4% and 70,000 euro valued for each year of life lost (net present value in millions of euros, period 2007-2107

	Zero alternative	Alternative 1	Alternative 2	Alternative 3
		Current policy	Emergency Locations	All locations
Costs				
Remediation Costs	1,400 (530-1,600)	4,500 (1,700-4,900)	3,800 (1,400-4,200)	8,500 (3,200-9,400)
Benefits				
Health inc. lung cancer cadmium	210-1,000 0-630	870-2,800 0-1,500	790-2,300 0-1,200	1,400-5,800 0-3,500
Inc. other cancers	100	600	570	780
Inc. IQ loss	110-280	270-680	210-540	620-1,550
Drinking water	1-40	2-100	2-80	6-220
Real estate	270 (-10 – +540)	950 (-30 – +1,900)	830 (-30 – +1,700)	1,700 (-50 – +3,400)
Other benefits (ecology, dissemination, more efficient spatial use)	pm	pm	pm	pm
Net balance	-90 + pm (-1,400 – +1,100)	-600 + pm (-4,100 – +3,200)	-580 + pm (-3,500 – +2,700)	-750 + pm (-8,000 – +6,300)

Source: own elaboration based on Van Wezel et al. 2007

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[38] F. Bonnieux, A. Carpentier, R. Weaver, [1998]: *Reducing soil contamination: Economic incentives and potential benefits. Agriculture, Ecosystems & Environment, 67 (2–3), pp. 275–288.*

[39] The World Bank, [1998]: *Handbook on Economic Analysis of Investment Operations. Washington, DC.*

[40] D. Lavee, G. Beniad, [2012]: *Estimating the value of non-marketable land in Israel. The geographical network, no. 5(1), pp. 1–10.*

The estimation of indirect costs and benefits is not yet based on a universal methodology, thus numerous CBA approaches may contain different input data, which results in a wide range of cost-benefit balance estimates. Another issue is uncertainty levels of some of indicators, such as a number of residents on a remediated site that would be exposed to contamination, health risks to the residents, cost and benefits of solutions other than remediation (conservation, relocating the residents), risks of recoil contamination, various impacts of the remediation project itself, etc. Uncertainty levels have an influence on the accuracy of the cost-benefit balance to such an extent that some authors suggest CBA being inapplicable to large-scale projects (Kornhauser 2000), although other scholars argue that CBA may be a productive mechanism for measuring effectiveness if the input information is regularly updated[41][42].

12.6.Evaluation of Innovation

Depending on the perspective, there are many ways to assess performance of a remediation project. Governments and policy-makers identify introduction of innovation as a criterion for evaluating results of technology deployment, as noticed by Spira[43]. While introduction of innovation is unequivocally a catalyzing challenge for innovation managers, for scholars and practitioners imbedding more than two evaluation methods in one project embrangles the laborious enough process of soil remediation.

Innovations in soil and groundwater remediation were estimated critically low in a 1997 research publication. Comparing traditional pump-and-treat technology against innovative technologies, it was found out that the barriers for implementing innovative remediation technology range from the site environmental conditions to regulatory obstacles and lack of trustworthy data on technology performance[44]. However, a more recent study on technology diffusion reveals that in-situ bioremediation has higher maximum technology adoption rate that in-situ chemical remediation and that social-economic and regulatory factors affect the adoption of remediation technologies[45]. In a guidebook “Evaluation of Innovation Activities. Guidance on Methods and Practices” innovation was qualified as “a complex phenomenon, difficult to quantify and with often long time lags before an impact can be measured”[46].

The need for introduction of innovative technologies was recognized by the European Commission (EC), which resulted in launching the European Co-ordination Action for Demonstration of Efficient Soil and Groundwater Remediation (EURODEMO) in 2006, one of the initiatives aimed to increase the availability of innovative technologies for

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[41] P. Misuraca, [2014]: *The Effectiveness of a Costs and Benefits Analysis in Making Federal Government Decisions: A Literature Review, The MITRE Corporation.*

[42] L. A. Kornhauser, [2000]: *Cost-Benefit Analysis: Legal, Economic, and Philosophical Perspective The Journal of Legal Studies, no. 29(1), p. 1037.*

[43] Y. Spira, J. Henstock, P. Nathanail, D. Müller, D. Edwards, [2006]: *A European approach to increase innovative soil and groundwater remediation technology applications. Remediation, no. 16, pp. 81–96. doi: 10.1002/rem.20103.*

[44] M. Cadotte, L. Deschênes, R. Samson, [2007]: *Selection of a remediation scenario for a diesel-contaminated site using LCA. Int J Life Cycle Assess 12(4), pp. 239–251.*

[45] D. Hou, D. O’Connor, A. Al-Tabbaa, [2014b]: *Modeling the Diffusion of Contaminated Site Remediation Technologies. Water, Air, & Soil Pollution, September 2014, pp. 225:232.*

[46] Technopolis Group and MIOIR, [2012]: *Evaluation of Innovation Activities. Guidance on methods and practices. Study funded by the European Commission, Directorate for Regional Policy. Brussels.*

effectuating sustainable development in Europe[47]. Another environmental innovation project partially funded by the EC is Eco-Innovation, which has developed SmartStripping® technology. The main benefit of SmartStripping® is a reduction of water consumption and gas emissions during soil and groundwater remediation on contaminated sites[48]. The German-Polish cooperative Terra-, Aqua – & Site Remediation Competence Centre Leipzig – TASK initiative sets its aim to promote and support innovation, technology and know-how transfer within the field of soil and groundwater investigation, remediation, and land revitalization[49].

Also The Institute of Natural Fibres and Medicinal Plants in Poznań, Poland is implementing the project Remediation Method of Degraded Land by Cultivation of Industrial Hemp in The Region of Liglife_logonite Mine Konin. This project seeks the methods of remediation of degraded areas as a result of application of new crop rotation systems and use of crops produced on post-mining areas as valuable, renewable raw material for cellulose and energy production. The project will create a model of soil remediation system and environmentally sound use of raw materials produced by cultivation of industrial crops, esp. industrial hemp[50].

With many policy-makers prioritizing innovation introduction and proliferation, the actual contour for innovations in remediation technology leaves much to be desired. To start with, innovative soil remediation is still widely perceived as any technology different from "dig and dump". Secondly, according to Hou, O'Connor and Al-Tabbaa even in the US, one of the leaders in environmental remediation industry, traditional methods of soil remediation (such as soil vapor extraction) prevail[51]. Third, some sites require up to 300 years, as reported by Cadotte, Deschênes and Samson, for a complete remediation cycle, which, on the one hand, creates some potential for midline introduction of innovative remediation technologies into current projects, but it also reduces the chances for full-scale technology approbation within the foreseeable future[52].

Evaluation of innovative technologies is commonly conducted by the researches themselves, who focus on quantitative output, i.e. higher performance level and lower costs as compared to the outdated technology. An exemplary case may be found in a 2009 work, in which the authors not only developed "an innovative stabilization/solidification (S/S) process using high-performance additivated concrete technology", but also conducted a brief cost evaluation and presented some long-term performance scenarios[53].

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[47] Y. Spira, J. Henstock, P. Nathanail, D. Müller, D. Edwards, [2006]: *A European approach to increase innovative soil and groundwater remediation technology applications. Remediation, no. 16, pp. 81–96. doi: 10.1002/rem.20103.*

[48] *Smartstripping. Emission-free Groundwater and Soil Remediation Retrived from http://ec.europa.eu/environment/eco-innovation/projects/en/projects/smartstripping.*

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In the presented example the evaluation of innovation does not exceed the standard environmental risk assessment. This case, along with many others, spotlights a range of issues general to innovation in many spheres: the relevance of the research results to social and economic welfare of the country/region, opportunities for investment into and commercializing of the technology, finally, channels to transfer the technology from scholars to the industrial-scale practitioners. The importance of knowledge transfer was emphasized by Wozniak[54]. Such transfer is further disclosed in the "sticky information" theory, which connects the issues of cost, acquisition and transmission of information to impact on technology innovation and diffusion and specialization of firms.

12.7. Social Dimension of Site Remediation

The idea of sustainable remediation emerged from the necessity to project the principles of sustainable development on remediation practices. Mechanisms for sustainability evaluation in environmental remediation have been developed and implemented by a number of scholars. Despite variations in approaches, researchers and policy-makers recognize the significance of tools and mechanisms for thorough assessment of remediation sustainability with a special emphasis on the social dimension. The social dimension is one of the triple bottom line dimensions along with the economic and environmental, but only recently it gained attention in connection to remediation practices as being a vital component of sustainability assessment.

The social dimension of a remediation project is too complex for any single tool to evaluate the overall remediation effectiveness in a manner that would allow obtaining holistic quantitative results. Furthermore, it is argued that a simple qualitative assessment of all possible social indicators is better than quantitative evaluation of a few, as indicated Harclerode et al.[55]. Various qualitative and quantitative tools for evaluating social impacts used by practitioners are presented in Table 4.

Table 4. **Tools for Evaluating Social Impact (various sources)**

Tools for Evaluating Social Impact	Description	Reference
Rating and Scoring System Evaluations	A rating metric that combines separate ratings into an overall score, which enables decision-makers to draw conclusions based on the results of the scoring. This tool's function is to eliminate the gap between quantitative and qualitative information.	Bargagliotti and Lingfang 2013; Petelina et al. 2014; Ridsdale 2015

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Social Sustainability Evaluation Matrix (SSEM)	An Excel-based tool that measures impacts in four social dimensions: social-individual, socio-institutional, social-economic and social-environmental. The socio-individual and socio-institutional dimensions have 18 measures that refer to impacts on standard of living, education, population growth, justice and equality, community involvement, and fostering local heritage. The socio-economic dimension has 11 measures that refer to business ethics, fair trade, and worker's rights. The socio-environmental dimension has 13 measures that refer to natural resource consumption, environmental management, and contamination prevention.	Reddy et al. 2014
Social Science Methodologies	Application of social science methodologies within a particular remediation project. The most commonly used methodologies are snowball sampling, interest-influence matrices and actor-linkage matrices.	Reed et al. 2009, Hart & Sharma, 2004
Social Network Analysis	Social network analysis assesses and quantifies stakeholder involvement in a remediation projects by calculating centrality of the stakeholders and cohesiveness of the whole network.	Bodin et al., 2011
Multicriteria Decision Analysis (MCDA)	Multicriteria models help evaluate conflicting criteria in order to make sustainable remediation decisions. Four major types of MCDA exist: linear additive models, single synthesizing criterion approaches, outranking approaches to synthesizing process, analytical hierarchy process (AHP). AHP is considered to be most widely implemented method in evolution social impact in environmental remediation.	Kain and Söderberg 2008; Harclerode et al. 2015
Enhanced Life-Cycle Assessment	A life-cycle assessment that is extended to social impacts and comprises land use assessment, toxicity exposure, carbon footprint and global warming potential.	Page et al. 1999, Diamond and Campbell 1999

Source: *own elaboration based on literature review.*

Measuring social impact encounters limitations and knowledge gaps. To start with, social impact is not always included into evaluation[56]. According to Favara et al. risk assessment tends to be the only method used to evaluate human risks during site remediation[57]. As the social dimension is one part of the triple bottom line, evaluating social impacts is conducted within three separate assessments with different methodologies, which inherently leads to inconsistent overall evaluation and further unequal trade-offs[58].

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Stakeholder collaboration is largely regarded as the key pillar in sustainable remediation projects, thus integrating divergent stakeholder perception enables adopting sustainable remediation practices, although incorrect identification or disengagement of stakeholders may induce project failure[59],[60].

12.8.Conclusions

This paper presented a variety of tools for remediation evaluation. Conducting extensive evaluation of the technology efficiency and effectiveness is not a simple task, which is further antagonized by the fact that each evaluation takes place on a site with unique characteristics. Consideration of various factors is the core part of an integrated assessment that helps identify the most sustainable and efficient procedure for site remediation.

Uncertainty about remediation technology performance might push practitioners to opt in favor of technologies that are already evaluated as ecologically effective, regardless of the unknown long-term social-economic impacts. Including (parallel with ecological evaluation) risk-based assessment or cost-benefit analysis should assist to determine which technology is more effective for a particular remediation project. Integrating tools to evaluate social impacts within the triple-bottom line of sustainability will provide positive insights on the remediation strategies.

The social dimension of site remediation is not only one of the most comprehensive tools to evaluate remediation, it addresses the contamination impact on the receptors within the exposed communities, incorporates stakeholder collaboration, promotes social and environmental justice, and contributes to local, regional and global sustainability polices. While many current literature and projects target internal aspects of remediation, it is already possible to foster the transition from traditional ecological evaluation to social approach. Support from policy-makers is required in order to formalize methodologies of measuring social impacts in remediation frameworks, whereas scholars should include evaluation of social impacts into development of new sustainable remediation technologies.

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Contacting authors:

Ivan Forafonov
Orel State Agrarian University, Russia
Mariusz Maciejczak
Warsaw University of Life Sciences – SGGW, Poland
e-mail: mariusz_maciejczak@sggw.pl