# Sustainable remediation in Brazil:

# Development, controversies,

# and future perspectives

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**Abstract**

Management of contaminated sites started being implemented in a more structured form in Brazil mainly in the 90’s. Since then, the management strategy and techniques have evolved significantly. For example, a site-specific risk-based approach was developed to define remediation goals and new remediation technologies were developed and are applied worldwide. However, more recently, it became apparent that the application of remediation techniques might have significant environmental impacts, such as waste generation and gas emissions, besides having a high demand for energy and resources. Consequently, the idea of sustainable remediation started permeating the contaminated sites sector. The paper presents and discusses how the concept of sustainable remediation started appearing in the Brazilian context and the controversies involved in its introduction and application. Despite not focusing on radionuclide contaminated sites, the discussions are valid for all kinds of remediation sites. For example, initially, there was a concern that the concept would be used to justify a non-action approach, resulting in higher exposure risks. Currently, there is an ongoing discussion on which levels should the remediation achieve, considering the need to restore impacted systems, the sustainability of the intervention actions and the risks involved. Finally, the paper presents our perspective on the possibilities and opportunities to apply the concept of sustainable remediation and the points that need further development.

## INTRODUCTION

Contaminated sites started being recognized worldwide as a significant environmental problem in the 1970s ( [1] [2] [3]). Initially, in most sites the remediation objective was to completely remove the contaminants, aiming to reach background levels of concentration. Later, in most places, this approach changed to a site-specific risk assessment, motivated by an increasing understanding of the risks associated with the contamination and of the technical difficulties in many sites to achieve background conditions. According to Slenders et al. (2017), this risk-based approach can be considered the second generation of contaminated sites policy.

In Brazil, contaminated sites also started being identified in the 70s, but the first regulations and guidelines to manage these sites were developed only in the 90s. Particularly, a collaboration between the Sao Paulo State Environmental Agency and the German government through the GTZ (*Gesellschaft für Technische Zusammenarbeit*) was primordial for human resources training and the development of an administrative organization and regulations. New guidelines and regulations were created based on what was being applied in other countries, such as the US, Germany and the Netherlands. Around the same time, the first consultant companies specialized in the subject started being created. In 2009, based on state legislation, federal legislation was created by the National Environmental Council (CONAMA), which was a milestone for contaminated site management in Brazil. [1] [4] [5]

To achieve remediation goals, different types of techniques and strategies have been developed. The first techniques were mainly energy-intensive solutions, such as soil excavation and removal (“dig and dump”), and groundwater pump and treat. In-situ treatment techniques were later developed and started being applied more frequently, mainly based on the injection of reactants to promote chemical and biological reactions. Other techniques that promote greater mass extraction were also developed, such as flushing, electrokinetic and thermal processes. Ellis & Hardley (2009) describe this change in approach as the evolution in the way of thinking about wastes and cleanups: it started in the 60s with just discarding wastes, evolved to intensive treatments in the 90s and then sustainable methods (based on recycling, reusing, transformation and biodegradation) started around 2000. In the State of São Paulo, however, intensive techniques based on mass extraction and treatment and disposal off-site, such as multiphase extraction, pump and treat and excavation are still the most used techniques, and are being applied in around 3300 sites in 2023. This is in great part a consequence of the real estate pressure to ensure quick remediation processes in sites that are going through a change in land use, being transformed from industrial to residential areas. However, some techniques considered more sustainable are also applied frequently. Monitored natural attenuation was applied in more than 600 sites, for example. Other in-situ treatment techniques (chemical oxidation and reduction, bioremediation, and thermal treatment) are increasingly being used, but correspond to less than 20% [6].

However, some of these techniques can also have significant impacts, such as high energy demand, resource consumption, waste generation and atmospheric emissions. For example, in one sustainability assessment, it was shown that the difference in CO2 emissions from two alternatives to remediate one site would be equivalent to 2% of the yearly greenhouse emissions of the State of New Jersey [3]. The recognition of these secondary effects created a need for assessing the remediation benefits from a more holistic approach, leading to the sustainable remediation concept [7]. Although different definitions of sustainable remediation are available, they usually consider that the remediation strategy must consider environmental, social and economic factors, achieving a net benefit between impacts and benefits. [8] [7]

## Sustainable remediation in BraziL: Status and Challenges

In Brazil, the application of the concept of sustainable remediation in decision-making is still very incipient. Initially, some stakeholders showed a concern that the concept of sustainable remediation could be used as a justification for no action. This is a typical perception that incorporating sustainability might decrease safety. According to Slenders et al. (2017), this concern is common when trying to establish more flexible policies, but can be overcome if the initial point is set as removing unacceptable risks.

Also, currently, there is a controversy regarding the application of site-specific risk assessment. In the current procedure (decision DD038/2017, for São Paulo State, for example), usually a risk-based approach is applied to determine the remediation goals, considering the risk to human health should be lower than the maximum defined by legislation, allowing a safe use of the site. In some sites, an ecological risk assessment is also demanded. The same procedure is applied in several countries worldwide. However, some argue that there should be total removal of contaminants or some compensation from a contamination that is left at the site. Then a controversy arises that the actions for a complete removal of contaminants could cause more impacts than benefits. [9] [10]

The risk-based approach also brings a discussion of what an acceptable risk is. In Brazil, the state and federal legislation consider that a site-specific risk assessment may be conducted, and that remediation must be performed to achieve acceptable risk levels for human health and the environment, based on a probabilistic approach. The acceptable risks are currently defined as 10-5 for carcinogenic compounds and a hazard quotient of one for non-carcinogenic effects. For sites contaminated by radionuclides, the dose limit criteria of 1 mSv/yr also applies. Social and cultural context are not considered in defining what is an acceptable risk, even though the definitions of risk pertain to cultural and social aspects [11]. In a research on risk communication, a position that appeared is that what is acceptable should be defined by those who experience the risk [12]. In this perspective, stakeholders must be listened to during the first steps of contaminated site management, and not only during technology selection.

Yet, the main applications of the concept of sustainable remediation in Brazil nowadays are during technology selection or deciding how to apply the selected technology. For example, using solar panels to operate a remediation system instead of the energy supplied by the power company. These applications of sustainable remediation are being conducted by some of the major consultant companies, and usually for multinational clients. Most of these sustainability assessments consider environmental (such as water consumption, generation of wastes and GHG emissions) and economic indicators, but not social. The methods being applied for the sustainability assessments and indicators being considered vary with the consulting company performing the analysis since there is no national or state guidelines available.

The lack of consistent standards and regulatory mandates has been identified as barrier to sustainable remediation worldwide [13] [5]. The same issues were identified for successful risk communication in contaminated sites in Brazil [12]. Risk communication is considered an essential part of contaminated site management, and it is crucial for sustainable remediation as it allows communication with stakeholders in a structured and efficient way. The Brazilian federal regulation for contaminated site management (CONAMA 420/2009) does not mention sustainable remediation specifically but mentions sustainable development as a general need. Risk communication is also mentioned as an action that must be performed, but the details on how and who is responsible for it are not clearly established. It is important to notice also that contaminated site management strategies and actions are very heterogeneous among Brazilian states. Even though there is a federal legislation, five years after its implementation half of the states in the country did not have a methodology for contaminated site management [4]. Only three states have a register of contaminated sites. Therefore, the number of contaminated sites in the country is largely unknown. Not knowing the extension of the problem decreases the perception of the importance of sustainable remediation [5].

The historical lack of transparency in treating environmentally sensitive problems is another issue to overcome when implementing more sustainable remediation approaches. In both conventional and nuclear industries, there is a tendency to withhold information to maintain control of the narrative and decision process. An OECD Watch report acknowledges the difficulties of the country in performing the best practices related to transparency for the society [14]. The report gives an example of the lack of confidence of the communities affected by the Mariana Dam collapse about the drinking water safety, after treatment, due to the lack of disclosure of the epidemiological and toxicological studies. The practice of not promoting, or even preventing, the stakeholders involvement during the assessment and planning of the remediation can damage the necessary bilateral confidence to discuss more sustainable remediation methods and limits. The same phenomena can cause unnecessary delays and create the need for more than reasonable monitoring and cleaning activities.

The lack of research and studies on sustainable remediation by Brazilian researchers is another barrier. Sustainable remediation assessments and guidelines must consider the specific conditions, goals and situation of the country and, therefore, methods developed by other countries should not be directly applied. The number of publications on sustainable remediation by developing countries, particularly Brazil, is significantly lower than those from developed countries [5]. Even though there are several tools available for sustainability assessments and comparison of techniques, most of these were developed in Europe and the US, which have completely different scenarios in terms of physical environment, economic, cultural, and social settings. One multi-criteria analysis (MCA) tool was developed by Brazilian researchers to evaluate remediation alternatives for urban sites impacted by nuclear accidents [15]. However, only technical, and radiological criteria were inserted in the model. In another study [16], the researchers developed a matrix for initial technology selection and a semiquantitative tool for sustainability assessment. Indicators were selected based on interviews with experts on the subjects of sustainability and remediation from different countries and did not include other stakeholders [17]. Both studies were published only in a doctoral thesis. That also shows another barrier, which is the difficulty for communication and sharing of knowledge and experiences between universities and the industry and governmental sectors.

This scenario found in Brazil regarding sustainable remediation application is in strong agreement with what was reported by Hou et al. (2016) for developing countries, in which respondents gave low importance to considering sustainability in remediation selection and indicated a low use of sustainability policies.

## Future perspective

Even though the application of sustainability concepts in contaminated site management is still uncommon in Brazil, there is clearly a movement in that direction. Some initiatives are becoming stronger and bringing the discussion closer to the stakeholders. For example, Brazil is part of the NICOLE – Latin America since 2015, a network for soil and water management, with representatives from the industry, consulting companies, and academy. In Brazil, NICOLE has a working group for sustainable remediation, which has generated discussion and production of materials on the subject such as a podcast. This group is also a part of the Sustainable Remediation Forum (SURF).

In the State of Sao Paulo, the environmental agency is currently revising its Contaminated Sites Management Guidance. In its new format, it mentions that the selection of intervention action must consider sustainability aspects, contemplating environmental, economic, and social dimensions. It defines that the selected alternative should be the best environmental alternative, cost feasible, and promote social gains. The São Paulo State environmental agency is also discussing sustainable remediation in the Environmental Chamber for Contaminated Sites Management, which also has representatives from the industry, academy and services, besides the regulators.

Also, there is an increase in Brazil on research towards the development of Nature-based Solutions (NbS). These are more holistic solutions, that are an alternative to traditional remediation techniques, bringing us closer to achieving more sustainable remediation options. NbS have multiobjectives, bringing environmental, social, and economic benefits. [18] The concept is that NbS can increase resilience in the face of climate change and improve ecosystem services offered by land use. NbS must be developed locally, as they are based on natural processes. Therefore, the development of research in Brazil on the topic is crucial to allow its implementation. Also, the dissemination of the results among consultants, regulators and others must be performed to achieve higher impact.

The discussions on the topic of sustainable remediation in different settings, institutions and groups of stakeholders are important to disseminate the concepts of sustainable remediation and for the creation of a local understanding of sustainable remediation and its goals. This development is the first step in the creation of guidelines and regulations for sustainability assessments. However, it can be noticed that the ongoing discussions rarely involve the ones affected or potentially affected by the risks. This can be a consequence of what is considered a technical approach to the detriment of a democratic approach, parallel to the definitions used in risk communication. In the technical approach, the communication is unidirectional from the “experts” to the impacted community. In contrast, in democratic risk communication, the dialogue occurs in both directions, and the risks and objectives are assessed considering political and societal context.

To achieve the third generation of contaminated land policy, defined by Slenders et al. (2017) as sustainable land management, sustainability should be considered from the start, since the definition of objectives, should involve all stakeholders. This would allow an integrated perspective considering ecological and societal settings. This type of approach can be applied and be beneficial to all remediation site projects, including radionuclide contaminated sites.

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