Challenges of Mine Remediation Programmes in Developing Countries – A Life Cycle Perspective – 15371

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ABSTRACT

This paper analyses some challenges of environmental rehabilitation (ER) projects in developing countries that the authors have encountered over the past two decades in many parts of the world, discusses the reasons and proposes ways to mitigate them. In the life cycle of an ER project, some stages that are particularly decisive for the lasting rehabilitation success are considered here: (1) site characterisation/baseline studies, (2) justification and development of remediation objectives, site end states and a remediation strategy, and (3) the after-care phase. This paper argues that the time available in many ER projects in developing countries using international funding is very often insufficient, and discusses the reasons for some of the most important bottlenecks: (1) time realistically required to produce thorough baseline data and obtain historic site information that are indispensable to develop a robust remediation design, (2) lack of an adequate legal and regulatory framework, overlapping and/or conflicting provisions of national standards and discrepancies with international best practice, (3) unmanaged stakeholder expectations regarding the actual health and environmental risks, justification and prioritisation of remedial actions, and the achievable remediation end state. Insufficient resources for after-care, monitoring and, if required, corrective action is another major issue that, in the experience of the authors, jeopardises the sustainability of remediation success. Consequently by applying the lessons learnt from previous ER projects in developing (and developed) countries and taking them on board during the programming phase of new ER projects, international funding agencies could greatly help to avoid these obstacles.

INTRODUCTION

Environmental remediation (ER) of legacy sites is a global mission, but often falls under the responsibility of local authorities. Implementing remediation measures not only has to ensure the safety of humans and the environment with respect to radiological and non-radiological risks, but should maximise, with the resources available, the benefit from remedial action for the affected communities [1]. Most environmental remediation programmes for radioactively contaminated sites in developing countries are planned and implemented under serious financial and time constraints, and with the support of international donor institutions such as the World Bank/International Development Agency (IDA), the European Commission and others. This includes remediation projects in the authors' domain of experience covering mining and mineral processing legacy sites contaminated by naturally occurring radioactive materials (NORM). There have been various attempts to analyse and mitigate these constraints, e.g., the IAEA's project to address constraints to implementing decommissioning and environmental remediation programs (CIDER) [2].

From a life cycle perspective, and following the methodology of Reference [1], an ER project can be broken down into the following phases:

1. Problem identification, especially at legacy sites that are not immediately present in societal and corporate memories and thus needs to be brought to the attention of decision makers, and prioritisation of individual sub-projects, e.g., on a national or regional level;
2. Programming phase if international financial support is required, coordination of funding agencies and donor organisations as appropriate, negotiation of funding conditions with the beneficiary country;
3. Project preparation, tendering and contracting of consulting and engineering firms;
4. Site investigation including historical site assessment;
5. Impact and risk assessment of the current situation and justification of remediation measures;
6. Development of remediation targets and end states, and hence of a remediation strategy;
7. Development of technical and/or institutional options to achieve the remediation objectives, and selection of a preferred option (optimisation);
8. Detailed planning and engineering of remedial solutions;
9. Permitting procedure by national regulatory authorities;
10. Contracting and implementation of remedial works and related measures; and
11. Evaluation of remediation success, monitoring and aftercare.

Obviously, challenges to the successful completion of an environmental remediation project and to the lasting rehabilitation success exist at all stages of an ER project’s life cycle. With respect to the success and sustainability of an ER project, the most critical stages on which the discussion in this paper will concentrate include:

- Site investigation and historical site assessment;
- Justification of remediation measures, development of remediation targets, end states, and a remediation strategy; and
- Post-remediation monitoring and aftercare.

A critical element common to all these stages is the time for completion of an ER project: it is usually under-estimated. This must not be misunderstood as a plain, indiscriminate call for “more time”. Rather, as we attempt to demonstrate in the remainder of this paper, experience shows that critical phases in ER projects inherently require more time than is usually built into the administrative and financial planning by funding agencies, both national and international. The aim of this paper is to raise awareness of decision makers in international funding and donor organisations and national counterparts for the complexities and pitfalls of ER projects, which seem to be all too often overlooked.

If remediation projects are financed with aid from international donor organisations, they are often designed as pilot projects, in which case consulting, technical, and engineering services as well as works are complemented by a significant training component and other forms of capacity building, with a view to accumulate sufficient in-country experience to reduce expensive input of international human, technical and financial resources in follow-up projects in the same country or region. This makes it even more important to learn from past project experience, so that money and resources spent on ER projects in developing countries can be much more efficiently used. This paper aims at providing some input into this learning process.

CHALLENGES AND PROPOSED MITIGATION

Site investigation and historical site assessment

It is common sense that site investigation is an indispensible prerequisite of any ER project [3], [4]. A thorough characterisation of all relevant aspects of a site, including but not limited to the contamination situation, is the indispensable basis for justification of any remediation works. It defines the remediation strategy and eventually the technical measures to be engineered and implemented. Site characterisation is also a decisive ingredient for the assessment of environmental and social impacts (ESIA) that is required in most ER projects as part of the permitting process. It is best practice to carry out baseline studies for key environmental disciplines such as meteorology, hydrology, hydrogeology or biodiversity over a period of at least 12 months (i.e., one hydrological year or a full vegetation cycle). A thorough meteorological and hydrological baseline is a *conditio sine qua non* of a defensible design of hydraulic structures such as diversion channels, spillways, and retention/settling ponds and, if required, more advanced water treatment systems. These structures are decisive in ensuring long-term stability of waste management facilities such as tailings ponds and waste rock dumps, but also for the dewatering of underground mines. Apart from current meteorological data, historical records are required to estimate design rainfall events (e.g., 1 in 10,000 year storm events, design floods and similar information).

Existing datasets may help reduce the baseline monitoring programme to a certain extent, but reliable data in the required quality are rarely available, let alone at short notice for a project with a design phase of a few months. The only way to lay the foundations of a robust remediation design is to devote sufficient resources to baseline data collection of sufficient quality. This includes not only human and technical resources that must be properly budgeted for, but first and foremost a realistic estimate of the time required to complete proper site characterisation and baseline studies including the necessary preparation of fieldwork activities. Short cuts have repeatedly proven a recipe for failure and make the design vulnerable to later scrutiny and independent review. Realistically a one year baseline data collection programme requires at least 15 months to set up, verify and complete.

Historical site characterisation is an important tool to collect as much existing information as possible and to avoid unnecessary duplication of work [5]. Very useful information about the nature, location and extent of contamination sources, water and waste management on site and other areas of concern can be extracted from historical documents and oral communication from former site operator staff. However, experience shows that if written information does exist, its release often involves a protracted process of negotiation with governmental agencies and former operators, to be able to use the document as an official source and to reference it in the ER project documentation as part of the design basis. Especially at uranium mining legacy sites, information security concerns reminiscent of Cold War thinking are often prevalent and may significantly affect the planning stage of an ER project. Consultants retained by funding agencies or national beneficiaries usually do not have any leverage to accelerate the process. Funding agencies may be in a much better position to agree a data disclosure policy with national decision makers in developing countries, especially in the project preparation phase when the role and responsibilities of local counterparts are defined as part of the funding agreement.

Justification[a] of remedial measures, development of end states and a remediation strategy

At uranium mining/processing and NORM sites that have been selected for implementation of an ER project, the mere presence of elevated levels of natural radioactivity leads many stakeholders to the expectation that extensive remedial measures can be justified by radiation safety concerns alone. However, in most of the many cases that the authors have been involved in, this preconception turned out to be unjustified.

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[a] The term Justification is used with the meaning in radiation protection, e.g., in [6], as “The *process* of determining whether a proposed *intervention* is likely, overall, to be beneficial [...] i.e. whether the benefits to individuals and to society (including the reduction in *radiation detriment*) from introducing or continuing the *intervention* outweigh the cost of the *intervention* and any harm or damage caused by the *intervention.”*

In fact, in reference [3] it was pointed out that factors such as geotechnical stability, access control, general site security and socioeconomic development considerations are most prominent and it is only rarely that radiological or health risks can be used to justify remedial action. Effective doses under realistic exposure scenarios are often negligible or well below any intervention reference level. In these cases, radiation protection aspects become only relevant once the decision to carry out specific remedial activities has been taken, and works involving radioactive materials require radiation safety precautions as part of the optimization procedure.

Concerns and consequently expectations towards remedial action are mainly fuelled by the following factors:

- Coverage of a site by media and interest groups (NGOs, research institutes) that are often exaggerated in terms of radiation risks[b] - a discussion of exaggerated claims of radiation and environmental risks can be found in [9];
- Often unrealistic perceptions of the local population regarding the general health impacts allegedly caused by the radioactivity at uranium mining and NORM legacy sites, where in fact poverty, malnutrition and lifestyles are the main determinants of poor public health; and
- The prospect of employment and development, albeit temporary, created by remedial activities in otherwise poor and often remote regions. Expectations reach far beyond the mere remediation of environmental legacies and often include infrastructure or regional development.

Nevertheless, perceptions drive decisions for or against proposed remedial options and can hold up the permitting procedure if people feel their concerns and expectations have not been sufficiently taken into account. Therefore, expectations of stakeholders must be carefully managed in order to (1) ensure support for the measures that are actually necessary, and (2) explain why more extensive measures may not be required and funds can be used elsewhere to better effect.

In some legislations, remedial action is formally required by very rigid standards that are not truly compatible with the optimisation (ALARA) principle (e.g., limits of radon exhalation rates from waste management facilities, or the requirement of a cover irrespective of any realistic exposure scenarios). Using realistic scenarios in the initial risk assessment, no remedial action would be required in many cases from a radiation safety point of view alone.

Significant time is required to discuss the available (and applicable) national laws, regulations and standards with regulators and authorities, reconcile contradictory or confusing provisions of the legal framework and agree with the permitting authorities on a set of remediation standards. This phase may require several months even if the national authorities are fully familiar with their regulatory framework, which is not always the case. This frequently leads to delays before clarity for the conceptual phase is established.

Once remediation measures can be considered justified, realistic remediation objectives and end-states are developed, which is then followed by the detailed remediation design. Again, this involves significant input from stakeholders, and usually requires several iterations until consensus is reached. Regulatory authorities, national and regional governments, as well as the local population must be consulted. At the same time, it is advisable to seek approval for the proposed remediation strategy (and a high level cost estimate) from the funding agencies to ensure the plan can actually be implemented. A more detailed discussion of the roles of the various stakeholders (site owners, regulators, governments, funding

[b] For example, the Blacksmith Institute [7] listed the Mailuu Suu uranium mining legacy site in Kyrgyzstan, Central Asia, among the ten most polluted sites, and The New Scientist [8] warned that the site would threaten the drinking water supply of millions of people in Central Asia, without a scientific substantiation of those claims.

agencies, local population and businesses) in the consultation process of ER projects is provided in the literature [10].

Requirements related to remediation measures under national legislation in developing countries are often very prescriptive, technically outdated (e.g., details on cover design for wastes), not adapted to the site conditions and therefore not necessarily considered international best practice. However, the Terms of Reference for ER projects using international financial support usually require that international best practice is applied. While common sense would dictate that outdated national rules should be ignored, considerable patience is required to convince permitting authorities that adopting modern approaches is in the best interest of the beneficiary country. Regulatory frameworks in developing countries are often not only restrictive but also partly contradictory and confusing, which makes it even more difficult for regulators to approve a proposed remediation strategy and detailed technical measures.

International funding institutions could greatly help improve the project environment by obtaining a firm commitment from the beneficiary countries as part of the funding agreement that international best practice takes precedence over national regulations where there is a conflict.

In summary, even with utmost project management efforts, many months up to a year or even more can pass before even a preliminary consensus is reached among stakeholders regarding the principal remediation strategy and detailed engineering design can commence. It should be noted that this proposed timeline for developing countries is short and optimistic compared to the time required in some ER projects involving radioactivity in developed countries.

Post-remediation monitoring and aftercare

Apart from the ER measures that can be implemented within a relatively short period of time, long-term and aftercare considerations must be taken into account when developing remediation end states and a remediation strategy. Questions on who will administratively take over the site, provide funding for aftercare, monitoring and organise corrective action if required cannot be disregarded at the project preparation stage if a sustainable solution is to be developed.

It has been pointed out by several authors [11], [12], [13] that a simple walk-away situation is not realistic at most closed and rehabilitated mine sites. Rather, continued monitoring and surveillance are required once the ER project has been implemented and works are completed. According to [3] monitoring always serves the purpose, *inter alia*, of triggering corrective action. This holds for the post-closure phase. Long term monitoring plans must always be linked to corrective action to be taken if a remedial solution does not function as intended. In other words, monitoring and inspection alone are useless unless it is determined how exactly the monitoring and surveillance data are interpreted and by whom, and what action is taken if the monitoring results indicate failure of a remedial solution. This requires sufficient financial means for both monitoring/surveillance and corrective action if necessary.

Responsibilities to implement after-care programs may be formally established, but require financial, human and technical resources that are often unavailable in developing countries. ER projects often lack long-term commitments for after-care. Although ER programs funded by international donor institutions are very often complemented by a training and capacity building component and/or delivery of monitoring and laboratory equipment, practical experience has consistently shown a high turnover of trained staff of site owners and regulatory authorities (and their staff) so that knowledge is lost. Likewise, due to the lack of trained and committed staff, equipment may not be properly operated and maintained.

The problem of unplanned post-closure liabilities and the need to provide sufficient funding for corrective action was extensively discussed in [14]. However, conventional instruments for after-care such as

Unforeseen Events Funds [15] or an insurance approach [14] are unlikely to work satisfactorily in developing countries.

As a consequence, in the authors' experience, post-remediation monitoring/surveillance and corrective action are usually not, or insufficiently, carried out in developing countries. This is regrettable, as the lasting success of ER programs is contingent on after-care. If necessary aftercare activities are not properly carried out, this may undo the success of costly remediation measures, which eventually is a waste of resources.

As developing countries, in most cases, do not have sufficient financial resources to implement after-care programs to ensure lasting remediation success, the logical consequence is that international funding programs for ER projects should include an adequate after-care component that includes monitoring and surveillance as well as a contingency for corrective action.

CONCLUSIONS

The overarching, and perhaps most critical issue in ER projects is time planning. In the authors' observation for projects in developing countries, it is not necessarily limited financial means as such that is the main problem, but rather over-optimistic expectations in the programming phase of ER projects with regard to the time required to properly and sustainably implement a project. In each of an ER project's life cycle, the challenges described above inevitably lead to delays that can only to a very limited extent be controlled by the involved parties once the project has started. It would therefore greatly benefit the success of a project if a more realistic (i.e., longer) time frame was adopted or at least more flexibility incorporated in the project planning. The following phases are most under-estimated in terms of time requirements:

- Site characterisation and baseline data collection;
- Common understanding of the legal and regulatory framework, reconciliation of discrepancies within the national framework and between national requirements and international best practice;
- Justification of remedial measures and expectation management; and
- Stakeholder engagement and agreement of remediation objectives, end states and a remediation strategy.

Other stages of an ER project such as engineering works are under the control of the engineers and consultants, and here they can far better commit themselves to delivery and completion timelines.

A project that involves site characterisation/baseline studies, initial risk assessment, development of a remediation strategy, detailed design, environmental impact assessment and stakeholder engagement would realistically require a total duration of at least three years until permitting and physical works can commence. This estimate is based on many ER projects that the authors have been involved in, and is in line with, or even shorter than timelines of ER projects in developed countries. It already takes into account that some activities can be implemented concomitantly, and project management optimised.

International funding institutions may greatly contribute to the minimisation of delays during project implementation by using their leverage during the negotiations with the national beneficiaries, obtaining a commitment on, *inter alia*, availability and disclosure of existing information and applicable standards and regulations.

Sufficient time must be allocated in the ER project programming phase when the budget lines and disbursement schedule are defined. Once the project has started and consultants and engineers are contracted, pressure is mounting to complete the conceptual and design stage within the available time, and despite best efforts of all involved, shortcuts often become inevitable to meet a timeline that has been unrealistically short from the outset.

Experience also shows that resources in developing countries are not sufficient to ensure after-care including monitoring, surveillance and corrective action, despite great efforts of capacity building, know how transfer and supply of equipment. This may jeopardise the lasting success of ER projects implemented with international funding. We therefore recommend including a reasonable budget for after-care and corrective action in case of unforeseen events into the ER project funding for developing countries. The additional funds required are certainly small compared to the total costs of an ER project, but we strongly believe that this provision will enable the beneficiary countries to continue monitoring and surveillance and can avoid the achievements of the project from being undone due to lack of after-care.

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