Applying ORE to Balangero Asbestos Mine Dumps Environmental Rehabilitation Risk Informed Decision Making

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ABSTRACT: Twenty years ago the Balangero Asbestos Mine Dumps Environmental Rehabilitation (BAMDER) competitive bid was won by an engineering group supported by what was then called Risk Based Decision Making (RBDM). Thus it was demonstrated that including risk assessment through the design of a project, from cradle to delivery and including risk driven maintenance concepts brought value and a leading edge to the proponents. Recently NASA and the US Nuclear Regulatory Commission (USNRC) have brought forward a process called Risk Informed Decision Making (RIDM). Both RBDM and RIDM use probabilistic risk assessment (PRA) as a tool within the process. In this paper we will show the step by step RBDM procedure used for Balangero and highlight the subtle differences with RIDM. The differences are necessary to make the process accessible and economically sustainable for any civilian project, including, of course mining ones. 20 years post remediation lesson learned at BAMDER will be described, including remote monitoring made possible by drones and data treatment. RBDM/RIDM are presently deployed for a similar project in North America.

1 INTRODUCTION

Despite its small throughput, the Balangero asbestos open pit mine, located 35km N-W of Torino (Torino), was the largest operation of this kind in Western Europe. After bankruptcy the site was abandoned, including the tailings storage facility (dump located at 45°17' 40.51N, 7°31' 17.40E, Fig. 1).

There are similar examples of orphan mining sites around the world where tailings are responsible of long term public health issues. However, Balangero remains to date and to the best of our knowledge, the only example in the world where a rehabilitation has been designed using risk based decision making (RBDM), built and monitored for almost two decades.

The Balangero open pit was cut into the ridge of an elongated hill. The mill was located on one side of the hill and the tailings dumps on the other. In 1918, it was foreseen that the mine would extract 26,000 m^3 rock per year, but in 1961 the mine extracted 1.3 Mm^3 rock. In 1966 a new mill with a capacity of 25,000 metric tonnes of fiber per annum was installed.

2 TAILINGS HANDLING AND STORAGE

The dry tailings were lifted from the mill, located at the foot of the hill, by a conveyor belt (which partially ran underground) to a location near the ridge. From there they were conveyed to the opposite side of the hill, and then dumped over a natural slope with an approximate angle of 25 degrees from the altitude of about 830 m a.s.l. to the bottom of the valley at 580 m a.s.l. for final storage (Fig. 1, 2).

Fig. 1 ©Google 2017 the link displays a site map with various system's macro-elements

As the dumping proceeded, a total surface of about 250.000 m^2 was progressively covered by the storage with tailings thicknesses going from a few meters to an estimated maximum of 60m–80m, resulting in an estimated 60 Mm^3 dry asbestos tailings storage (Fig. 1). This dump, as well as all the production facilities, was abandoned when the mining company abruptly stopped its activities in the early '80s for economic reasons.

Fig. 2: Looking down slope: nearby houses, the Fandaglia Creek and the decant basin

3 REHABILITATION PROJECT REQUIREMENT AND MEASURES

In 1992 a public company formed by the Province of Torino, the Mountain Community of the Lanzo valleys, neighboring communities and other public stakeholders named RSA was mandated by the regional government of Piedmont to organize an international design competitive bid in compliance with regional bylaws. RSA became the "project owners" and contract holders. The goals of the competition and the proposed measures can be summarized as follows:

- select the best possible alternative to increase the stability of the slopes (over-steepened, critically eroded and prone to mudflows). Gravity and water are the main combined external agents posing a threat to the stability of the over-steepened slopes of the dump. Thus, it was necessary to act:
  - against gravity to enhance the stability of the slope and
  - against water to eliminate surface erosion, gullies formation and increase of saturation triggering frequent mudflows along the slope.
- reduce the dispersion of fibers (long term hazard to the neighboring population). The entire restoration process had to include dust minimizing procedures which ended up driving the choice of:
  - excavating, hauling and
  - disposing equipment on the steep slopes.
- re-vegetate the slopes for aesthetic and environmental reasons as the storage is in a densely inhabited area at the Alps foothills (Fig. 2). As the dump material is highly sterile and generally too steep to retain humus, a special program of tree and shrubs planting was designed including the plantation of grasses, 45'000 shrubs and trees:
  - their root system was treated with selected fungi helping the rooting/vegetation process in the sterile slope.
  - A general hydro-seeding of the full area was undertaken step by step, operating remotely, from a helicopter, again to reduce disturbance to the steep slope.

4 USING RISK TO DEFINE THE PROJECT ROADMAP

One of the major challenges faced by this project was related to the amount of fiber contaminated material to be excavated and disposed of within the mine area in order to unload the over-steepened head of the dump slope. Between the top and the bottom of the slopes 4.5 km of dirt track were present. The preliminary design demanded for the removal of about 280,000 m^3 of residues (mainly sand and gravel) with mixed random asbestos fibers. It was obvious that beside technical hazards and resulting risks there was a strong social, public health component and neighboring communities had to be part of the development in addition to regulators and related authorities.

It is was also clear to the design team that risk and uncertainty analyses can and will always be challenged by opposing stakeholders not satisfied with probability assessments based on their subjective, modeled or even „pseudo-statistical" approaches. Under the excuse of limited or poor available knowledge of the problem at stake some stakeholder may invoke the „unrepresentative" character of expert analyses, „mistrust" in the results (as their gut feeling is self-assessed better than a science based approach) to avoid making a sensible decision.

During the implementation of decisions, it is common practice for decision-makers to seek for further protection by adding conservatisms and using traditional engineering frameworks of "defense-in-depth." This is typical of deterministic approaches to hazard and risk management, where layers of protection are added, without explicitly evaluating their effectiveness, to bound known uncertainties to, for example, „credible thresholds." However, these approaches have:

- limited effect in reducing the "unknown unknowns", i.e. reducing the completeness uncertainty.
- They can lead to unsustainable mitigations or to misallocate mitigative budgets.

In particular, these approaches may lead to censored results as they:

- identify a group of failure events sequences leading to credible worst-case accident scenarios called design-basis accidents;
- predict their consequences “with a single magic-number”;
- design appropriate safety barriers which prevent such scenarios and protect from, and mitigate, their associated consequences only

As a matter of fact, accidents in all sorts of industries have shown that the „credible“ scenario established in this way oftentimes represent a strong censure of the possible and actually credible ones; codes are generally not covering the full breath of situations that should be covered; mitigations result severely under estimated or misallocated.

The underlying principle has been that if a system is designed to withstand all the individual worst-case credible accidents, then it is “by definition” protected against any credible accident. That does not cover for uncertainties, interdependencies and common cause failures (CCF) which unfortunately do characterize accidents in our complex systems.

Given the complexity and the intricacies of the Balangero project, the design team abandoned the common “engineering approach” described above and accepted to be supported by the systematic application of Risk Based Decision Making based on the deployment of a set of probabilistic techniques which were later consolidated into one platform called ORE (Optimum Risk Estimates, ©Oboni Riskope Associates Inc.) (Fig. 3).

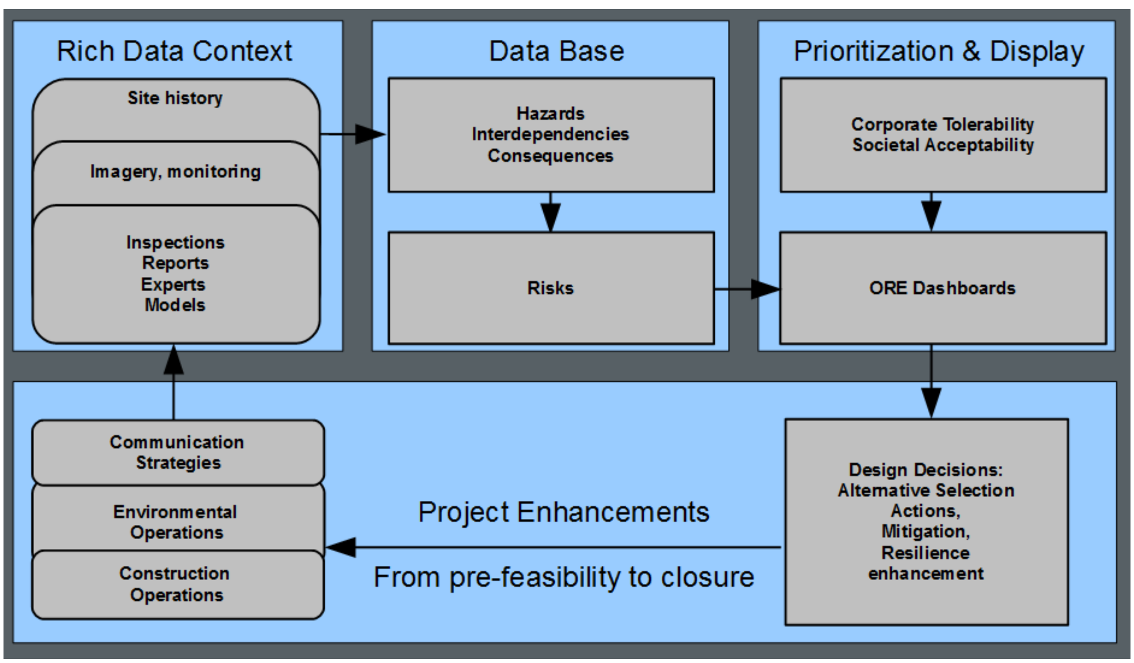

Fig. 3 ORE (Optimum Risk Estimates, ©Oboni Riskope Associates Inc.) scheme/ flow chart

Recently large organizations such as NASA and USNRC have published documents referring to Risk Informed Decision Making (RIDM) a technique that bears astonishing similarities to what was used at Balangero. It is comforting to see that, once in a while, what miners do is not only “moving rocks and dirt” but can be used to “go to the stars”.

RIDM requires to acknowledge uncertainties, multiple hazards, multiple stakeholders and compliance needs, integrating stakeholders' concerns and perceptions.

ORE and the RBDM approach used at Balangero:

- included the uncertainties by working with ranges. As a matter of fact the key point is to guarantee that uncertainties are taken into account in each step of the risk assessment. Uncertainties have to be:
    - systematically identified and classified;
    - represented and described by rigorous mathematical approaches;

    - propagated through the steps of the risk assessment procedure onto the risk measures until the decisions.
- allowed to integrate
    - multiple concerns (multiple stakeholder expectations) and
    - information sources as well as
    - multiple hazard types (natural, man-made, technological, etc.).

This lead to greater stakeholder participation in decision-making, in which technocratic decision processes, driven purely by rational technical considerations, were modified to integrate the concerns and the perceptions of stakeholders.

Thus, the match between ORE RBDM and modern RIDM requirements is perfect.

Modern RIDM requires the classic engineering/technical approach to risk assessment which includes:

- safety margins (Factor of Safety),
- engineered redundancy and diversity to prevent and reduce the impact of failures

and stochastic analysts based analyses such as:

- Interdependencies
- Common Cause Failure
- Scenario building and
- Extreme event analysis

to be integrated in the decision-making process while recognizing that all the aspects of a given system under consideration may not be known or ready for analysis simultaneously at different stages of a project/operation development/life.

ORE builds a hazard and risk register that will accompany the project/operation thought its existence. The register is:

- scalable, meaning it is built in such a way that different levels of knowledge can coexist in different areas.
- Drillable, meaning that it is always possible to perform queries on the threats-from, threats-to, per process thread, etc.
- Concise, meaning it avoids double counting and fuzzy statements.
- Economical, meaning information is never wasted, there is never the need to „start-over“, even if considerable amount of new information becomes available.
- Updatable, if necessary and if data available, up to real-time.

All the argumentation behind the analysis itself, including the assumptions, hypotheses, parameters and their uncertainties can be transparently laid out for disclosure points (however ORE register structure and numerical techniques remain proprietary).

Thus ORE RBDM was already fulfilling RIDM requirements and provided decision-makers with a clearly informed picture of the problem upon which they can confidently reason and deliberate.

Building trust with Stakeholders not satisfied with probability assessments was possible by deploying ORE within a RBDM/RIDM process. The approach helped achieving success by:

- supporting the selection of decision alternatives,
- ensuring that decisions between competing alternatives were taken with proper awareness of associated risks all along the life cycle of the operation/project.

When applied to projects ORE RBDM/RIDM helped avoiding usual project management hiccups like: late design changes, which can be relevant sources of risk, cost overshoot, schedule delays.

5 MAIN RESULTS BROUGHT IN BY USING ORE RIDM

The systematic application of ORE RBDM/RIDM at Balangero brought to develop a series of unusual solutions.

The use of hauling trucks was quickly discarded due to:

- environmental risks,
- air pollution from exhaust fumes and
- fiber dispersion from the excavated material together with the need to upgrade the tracks to roads.

A far better overall multi-hazard risk profile was obtained by installing a temporary aerial tramway (Fig. 4). This device was designed with a single span of 960 m between the two terminal stations to avoid building a tower foundation at mid-slope.

The aerial tramway had a bucket that allowed unloading at ground level as it was possible to lower it from “travel position” to “unload position” anywhere along the tramway path. The layout was selected to minimize lateral movements and allow building a buttress (slope stability enhancement) directly under the tramway.

The cable car was removed at the end of the earth movement works. The excavated material was wetted at excavation time and remained wet during the full trip from the source to the final resting position to reduce fiber dispersion.

Fig. 4: Aerial Tramway for hauling down material. Braking of the tramway produces electricity which is sold to the grid.

Fig. 5: Planted and seeded « pathway » after completion.

The process proved very efficient and only a couple of times, with very strong winds, the dust monitoring instrumentation displayed critical concentrations of aero-dispersed fibers in the surrounding area environment.

The aerial tramway produced electricity which was sold to the grid further reducing the carbon footprint of the project.

6. A REVIEW OF THE OVERALL PROCEDURE APPLIED AT BALANGERO

The overall rehabilitation procedure can be summarized as follows:

• Unload of the upper part of the slope by digging three 10m high berms (Fig. 6) and by storing the excavated material at the bottom of the slope on an artificial earth fill 8 m high using the cable car. The engineered fill is geared towards protecting from possible residual mudflows originated in the steeper eastern part of the slope (up to 42 degrees) the lower part of the slope, the Fandaglia creek etc. (Fig. 1, 2).

• Cut a series of 8 “path-ways”, i.e. small berms 2.5 m wide, along the slope at regular height intervals (Fig. 5). The “pathways” are each about 600 m long and were designed to minimize the volume of material to be evacuated. Indeed, the material excavated upslope is deposited down-slope in the same cross section. This procedure dramatically reduces the hauling needs down the slope in the steepest part of it, thus the minimization of fibers dispersion in the atmosphere during works. Furthermore the “pathways” create an access to the slope for present and future works/observation. The “pathways” are reinforced with small palisades built with wood logs (20 cm diameter on the average) increasing the use of natural materials and reducing the need for concrete and steel. Earth totally covers the downhill-side palisades, whereas the uphill palisade remains visible. It is complemented by a geogrid and densely planted to obtain, once vegetation is mature, a “green retaining structure”.

Fig. 6: Runoff collection channel on a top berm. Grass has already covered the remodeled sterile fills.

• Build whenever deemed necessary composite wood-earth structures to retain the steepest parts of the slope, or create necessary platforms.

From the hydraulic/water control point of view, surface erosion created deep (up to 3 m) gullies on the slope in the past. The remedial measures undertaken are the following:

• General control of all the surface water falling on the area in form of rain or snow via a net of small wooden channels (on the average 0.5 m to 1.0 m wide). These channels collect surface runoff on the slope thanks to the access created via the top berms and intermediate “pathways”. The small dimensions of the channels have been designed to limit the use of heavy equipment on the slope and the need for large excavations for their construction.

• The collecting system is relayed by secondary segments of channels located running on top of the berms and on the "pathways" (Fig. 5).

• The collected runoff is concentrated into four main channels located on the slope along the steepest gradient: these channels – called "water chutes" – are built with wood logs and stones (Fig. 1,7).

• The four "water chutes" finally converge into a unique main canal – built again just with logs and stones – that allows the outflow to reach the Fandaglia creek at the foot of the slope. Before release to the external environment the collected runoff water flows through a decant basin where the fine material and the fibers can be retained (Fig. 2).

Finally, sub-horizontal drains were drilled on the slope to control underground water.
RSA, the owner of the project, produced in 2015 an interesting short movie of the works geared toward main-stream public information.

6 CLOSING REMARKS

Balangero's asbestos mine environmental rehabilitation international competitive bid was won by an engineering group supported by Risk Based Decision Making (RBDM). Today a similar approach is used by large entities under the slight different name of Risk Informed Decision Making.

By winning the international competitive bid it was demonstrated that including quantitative risk assessment through all the phases of the design and construction of a project, from cradle to delivery and including risk driven maintenance concepts brought value and a leading edge to the proponents.

Fig.7: Aerial view of the site. Horizontal pathways and one water chute are visible, as well as pre-existing deep erosion features.

Examples of decisions that were risk-analysis driven and delivered a winning hand to the proponents:

- replacing classic truck-hauling with an aerial tramway,
- reducing the project carbon footprint by using local material and producing electricity (when braking the aerial tramway)
- reducing the volume of displaced materials by creating an earth buttress
- fostering plant growth by carefully selecting species, using selected fungi and
- minimizing future erosion potential (regular maintenance plan).

Since completion the site has endured the passage of climate-change related events (Medicanes, or Mediterranean Hurricanes), and has been monitored by various means, including drones and classic geotechnical instruments.

By using the ORE (Optimum Risk Estimates, ©Oboni Riskope Associates Inc. www.riskope.com) quantitative risk assessment platform it is not only possible to develop all the required preliminary risk evaluations, but also to include new information (as from monitor-ing, for example) as it becomes available, producing regular multi-hazard risk landscape dash-boards. These allow decision-makers to understand the evolution of the site and proactively generate road-maps for the maintenance.

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