Pyramids, Toxic Wastes & Nuclear Reactors Containments. A Lesson Drawn from History with a Risk Manager Perspective.

Franco Oboni, Cesar Oboni

Oboni Riskope Associates Inc., Vancouver, www.riskope.com

Risk Assessments for "perpetuity" (geo-engineering) projects, i.e projects that should last "forever" and/or receive "perpetual care", are raising in number and criticality. These project are oftentimes linked to the storage of wastes containing toxic, not easy to neutralize, not necessarily radioactive, compounds. No prior Human generation had to tackle this problem because: a) produced volumes were insignificant or b) there was no real understanding of "perpetuity".

This paper compares the "historic" world-wide rate of major accidents of Tailings Dams and Nuclear Reactors to previously published acceptability criteria and codes. The paper shows how a generic modern "excellent quality" dam probability of failure can be estimated, how the initial probability of failure will evolve during the dam life, as care and monitoring are released in the post production phase and under different hazards. The paper then explores selected Human geo-structures survivability experience and finally suggests a model for long term risk evolution of Tailings Dams, with particular emphasis on post production/closure.

Keywords (max. 5). Risk, Assessments, Perpetuity, Tailings-Dams, Nuclear Reactors

1. Introduction

Humanity is confronted for the first time with Risk Assessments for "at perpetuity" projects, that is projects that should last "forever" and/or receive "perpetual care". These project are linked to the storage of wastes containing toxic difficult to neutralize, but not necessarily radioactive, compounds. We will first compare the "historic" rate of failure (major accidents only) of Tailings dams and Nuclear Reactors world-wide to public acceptability criteria and codes, then define the long term evolution of the risks (major accidents) generated through the life of a Tailings Dams (TD), focussing on the long lasting post-production phases/closure.

Models and data used in this paper were published in 2013 (Oboni and Oboni 2013).

2. Tailings dams (TDs) and nuclear reactors' failures

Rates of TDs failures and major nuclear reactors' accidents to date were empirically estimated and both are compared to societal and technical acceptability thresholds to understand if present and foreseeable performances are aligned with expectations (Oboni and Oboni 2013). Risk is defined as the product of the probability of failure by the related consequences expressed in casualties, leaving aside all other environmental and physical direct or indirect consequences, for the sake of simplification.

2.1 TDs rate of Failure and long term behavior forecast

As reportedly slope instability is the highest cause for TDs failures, this paper focusses on that particular failure mode. The proposed methodology could, however, easily be expanded to cover other failure modes.

Where	**When (decade)**	p_f	**Approx** p_f
World-wide	Around '79	44/(3,500*10)	10^{-3}
World-wide	Around '99	7/35,000	$2*10^{-4}$
US	Around '79 & Around '99	7 or 8/(1,000*10)	7 or $8*10^{-4}$

Table 1: summarizes the historic rate of failure of Tailings dams around the world.

If we consider the hydro dams failures in the decades 1989 and 1999, based on an "average number of dams" of 30,000, we get $p_f = 3*10^{-6}$ to 10^{-5}. The statement above is in good agreement with the common understanding and empirical knowledge that TDs are generally of "lesser quality" than hydro dams. Interestingly many different industries around the world consider values below 10^{-6} to 10^{-5} as the boundary of what is humanly credible (meaning that below that range of probability an event is generally considered "incredible").

The Silva et al. 2008 methodology is used to estimate the p_f of "excellent" TDs at 10^{-5} to 10^{-6}. "Excellent" means top quality structure, well engineered, undergoing serious QA/QC, with a minimal Factor of Safety (FoS) of 1.4-1.5. Should inspections become occasional and measurements/monitoring ceased the probability will raise to $6*10^{-5}$, a value also obtained using the Silva et al. methodology.

It is also possible to “simulate” TDs long term complete abandonment. For example, if we look at the case of phased release from operational life down to long term closure, the probability of failure will increase each time the standard of care is released. For initial FoS in the 1.3 to 1.5 range, the difference between operational, we are assuming that the dam under examination is initially an “excellent” structure, and abandoned varies respectively between 1.5 and 2 orders of magnitude: for FoS=1.5, $p_f=10^{-6}$, with possible increase to 10^{-4} and higher if the same structure falls in total neglect.

2.2 Major Nuclear Accidents

As of Feb. 2, 2012, 435 nuclear power plant units with an installed electric net capacity of about 368 GW were in operation in 31 countries and 63 plants with an installed capacity of 61 GW were under construction in 15 countries. The cumulative nuclear reactor operating experience amounted to 14,745 years.

To date the world has seen the occurrence of a number of major nuclear reactors accidents (rated 5 and above on the International Nuclear Event Scale by the International Atomic Energy Agency). For Fukushima we consider one accident, although more than one reactor was involved, to ensure the list is made of “independent” accidents. Assuming seven accidents, the “historic” world average rate of Scale 5+ accidents is: $4.75*10^{-4}$ Scale 5+ accident/annum.

Level 5	**Level 6**	**Level 7**
Accident with wider consequences	**Serious accident**	**Major accident**
First Chalk River (1952) Windscale (1957), Lucens (1969), Three Miles Island (1979)	Kyshtym (1957)	Chernobyl (1986) Fukushima (2011)

Table 2: Worldwide accident of Scale 5+

This value is rather unexpected as is falls well within the realm of credibility and compares to the range of Tds. The surprise is even higher when considering the high level of regulation of one industry compared to the other.

Comparing risks of two very different industries 2

Figure 1 displays acceptability criteria developed independently by various authors over more than thirty years (Morgan and Lave 1990, Whitman 1984, ANCOLD, 2003). ANCOLD 2003 acceptability criteria (Fig. 1) are compatible with Comar (1987), Wilson & Crouch (1982) and later criteria published in the field of chemical industry, such those from Renshaw (1990) who defined societal risk acceptability as fatality of one individual per year of risk exposure. Many reputable publications point at a probability (of a casualty per annum) of 10^{-4} (similar to ANCOLD lower bound) as being the limit of “safe”, however with a lower limit of 10^{-6} for unwillingly exposed public.

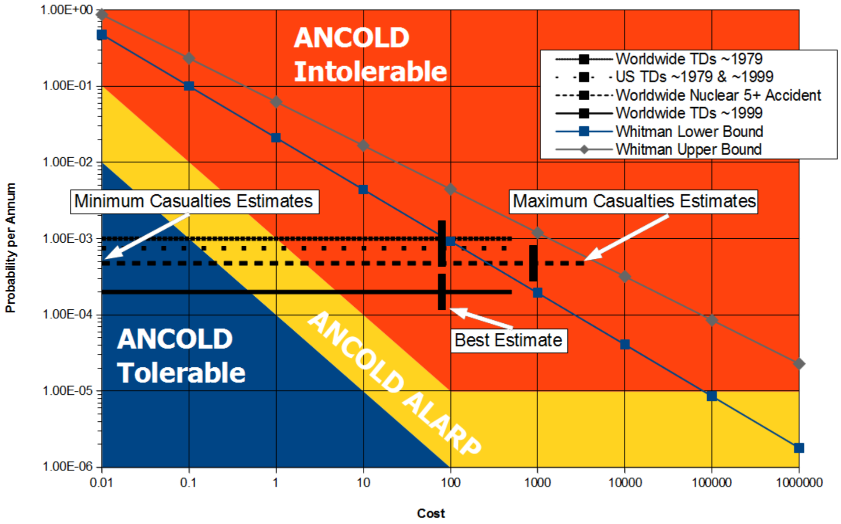

Figure 1. Different acceptability criteria

“Simplified” metrics are difficult to apply to nuclear accidents, because of the long delays to health effects. However, if we look at Whitman tolerability thresholds the Nuclear accident fall in the “could be” considered intolerable area. The TD 79-99 failures fall within societal acceptability lower bound, unlike the more ancient period or US failures. Should a TD be abandoned and undergo on the long run a number of natural hazards hits, the risks will become socially intolerable even if there are less than ten casualties.

Human geo-structures past experience 3

When looking at ancient Man-made structures to attempt to draw some conclusions on long term survivability, we can cite the following: Europe Tumulus of Bougon 4800BCE; Africa Pyramid of Djoser 2667–2648 BCE Earliest large-scale cut stone construction; America Sechin Bajo 3500 BCE the oldest known building in the Americas and also, however way more recent, Cahokia. Apart from the Tumulus of Bougon, these structures are very similar, both in shape, size and they are numerous. Aside these pyramids we only know a few dozens of older excavated structures. Pyramids represent the largest family of long-term easily-visible surviving structures around the world and are a feature of many civilizations.

We are not implying that the builders understood what shape would “hold” through millenia . We are only noticing long term survivors belong to the same type of structure, independently of their purpose. Thus we can see a similarity with our modern need to indicate, forever, that a given site contains large and toxic hazardous matters.

So what “did work” and what lesson can we draw to define the design parameters of a “sign post” which should last forever (or at least a very long time) and be visible enough to trigger the attention and care of passers-by even in a distant future?

We can draw two set of conclusions:

Technical side:

Unless a TD is designed, built and cared-after like a hydro-dam, which means “at perpetuity” high level monitoring and care (TD cannot be breached, unlike hydro dams) no residents should be allowed downstream of the said structure, within reach of possible run-out from a breach, to ensure ANCOLD compliance. Risk assessments have to be sophisticated enough to allow p_f estimates compatible with the ANCOLD tolerability thresholds. Standard practice matrix-based risk assessments Oboni et al. (2013), C. Oboni, F. Oboni, (2012) cannot be used as they lack the necessary finesse and resolution and could actually severely mislead TD owners/operators to the point of exposing them to severe liabilities.

Historical side:

Do not use a living creature, not even a very long lasting tree as it’s too vulnerable, use carefully selected rock, if possible without any mortar or filled joint (physic-chemical alteration, air contaminants, acid rain, etc.) . Make it big, so that even future deposit of alluvium, soil etc. will not easily cover it. Make it massive, no openings, or sealed ones. Make it wide so that it will accommodate differential settlements, will not topple even if parts are removed (vandalism, terrorism, wars, etc.). Carefully select foundation/location. Make it steep, so rain water will ‘flash-wash’ the faces and eliminate vegetation, grasses, etc. Make it flush (the Great Pyramid was flush until recently, with sharp angles, so it cannot be confused with a natural feature even if it gets partially eroded or if it is “buried” under wind blown sediments etc. Create myths and a specific clergy, caretakers forever, make sure legends will convey a sense of danger and mystery, so that future generations will respect the “symbol”.

References

ANCOLD, International Commission on Large Dams, Australian National Committee. Guidelineson risk assessment, 2003

C., Comar, "Risk: A pragmatic de minimis approach." In De Minimis Risk, edited by C. Whipple, pp. xiii-xiv. New York: Plenum Press, 1987

G., Morgan, L. Lave, Ethical considerations in risk communication practice and research, Risk Analysts 1o, 355- 358-, 1990

F., Oboni, C., Oboni, Factual and Foreseeable Reliability of Tailings Dams and Nuclear Reactors: a Societal Acceptability Perspective, Tailings & Mine Waste, Banff, 2013

F., Oboni, C., Oboni, Zabolotniuk, S., 2013, Can We Stop Misrepresenting Reality to the Public? CIM 2013, Toronto, 2013

F. M., Renshaw, A Major Accident Prevention Program, Plant/Operations Progress 9, no. 3 (July), 194-197, 1990

F. Silva, T.W. Lambe, W.A. Marr, December, “ Probability and Risk of Slopes Failures”, JGGE, ASCE, 2008

A.C., Wilson, E., Crouch., Risk/Benefit Analysis; Ballinger Publishing Company, Massachusetts. 1982. pp. 92-93

R.V. Whitman, Evaluating calculated risk in geotechnical engineering. J. Geot. Engineering, 110, 2, 1984