SAFE TUNNELLING IN A WATER RICH SHEAR ZONE IN THE WESTERN GHATS

Threat to the Kerala-Tamil Nadu water bodies from the India-based Neutrino Observatory

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"Ignorance of the things that we understand we should know but do not, leaves us vulnerable to unintended consequences of our actions".[1] Ellsworth.,W.L., Injection-Induced Earthquakes, Paper in Science, 12 July 2013.

"We're entering an era when a few individuals could, via error or terror, trigger societal breakdown."[2] - Martin Rees, Editorial in Science, 8 March 2013

"Tunnelling is a routine activity in mountains, under the rivers and seas, and even under mega cities. The technology has improved tremendously in the last few decades. It is hard to believe that such an activity can cause major or even minor earthquakes." BS Acharya et al in Current Science, 10 April 2013.[3]

"When the finger points to the Moon, the idiot looks at the finger". Chinese proverb, ancient, undated.

Summary

How will the Indian Department of Atomic Energy construct the biggest underground science laboratory in the world in a sheer zone in the Western Ghats, without repeating the hydro-geological disasters encountered in Gran Sasso in Italy, Rohtang in the Himalayas and Velligonda in the Deccan Plateau? This question regarding the negative impact of tunnelling of the India-based Neutrino Observatory on the nearby aquifers and surface water bodies in Idukki-Theni districts of Tamil Nadu, raised through peer-reviewed science, web and print media has been in the air since September, 2012. The State Governments of Kerala and Tamil Nadu ignored the issue and the Central cabinet has cleared the project. The first mega science project in India could have been launched after a detailed assessment of the short term and the long term impacts on the ecosystem. All reports should have been in the public domain, the pros and cons of the project should have been debated. This should have been followed by stakeholder consultancy at all levels. Without any of these, the Department of Atomic Energy and the Department of Science and Technology have decided to bull doze the Western Ghats with a million kg of gelatine.

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Introduction

The Department of Atomic Energy (DAE) has received the central government's final sanction for constructing the India-based Neutrino Observatory (INO), the biggest underground science laboratory in the world in Theni district of Tamil Nadu (TN), bordering the Idukki district of Kerala, in the underbelly of the Western Ghats (77°17′5.32″E, 9°56′46.20″N).[4] The surface facilities for the project are under construction over a 26 ha of common grazing land of Body village, taken over by the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. To create a finished volume of 235,000 Cubic meters, about 300,000 cub meters (800,000 tons) of rock will have to be blasted out using 1000 tons of explosives. The proposed site is in *the most degraded portion of the Suruli Shear Zone*, falling in seismic zone 3[5,] with maximum earthquake intensity around MSK VII. There are 12 dams storing 5 billion m^3 of water, the lifeline for six districts of Kerala and TN, all within a radius of 50 km from the proposed site, all receiving the flows from the three rivers – Periyar, Vaigai and Vaippar. The Idukki Dam on the Periyar River, one of the highest (169 m) arch dams in Asia, located 26 km from the proposed site is "listed as one of the 53 known global examples of reservoir-triggered seismicity". The 110-year-old Mullaperiyar dam, from which the INO will be drawing 400 m^3 of water daily, is at a distance of 50 km from the site. As the hydroelectric projects on these dams account for about two-thirds of the electricity generated in Kerala, more than 30 million people in the two states have a stake in the waters of Idukki. This is not a tunnel that links two cities or connects a water body with a needy region. The only requirement for INO is an overburden of a 1000 meters thick rock to filter out the cosmic rays. INO scientists initially sought a site with low seismicity, but finally ended up in a shear zone, with abundantly rich water resources, high population density and extensive agriculture.

Lack of Transparency in site selection

Singara village in the Nilgiris, the first proposed site for the project in 2005 was denied by the Government of India as it was closer to a wildlife park. Another site near the Siruliyaar was suggested by the Ministry of Environment and Forests, without undertaking any feasibility study.

As the local farmers revolted en masse, the present site was offered, also before conducting any study. The normal routine of comparison of alternatives did not happen in the case of INO. The environmental public hearing was conducted with heavy police presence, months before completion of the environmental impact assessment and the so-called geo-technical report.

Major safety concerns of the project

(a) INO's namesake geotechnical study did not look at the aquifers in the impact area, field visit (of five days) and drilling (four bore holes) were confined to a small area around the portal of project did not characterise the rock along the tunnel or in the main laboratory caverns. This report has been treated as confidential and is not available on the website of INO.

(b) Blasting in the shear zone can damage the underground aquifers and hence impact the flows of water

(c) Heavy use of novel chemical compounds used for stabilisation etc can poison the groundwater

(d) As per the EIA about 40% of the impactable area of the project lies in Kerala state. The project did not receive the approval of the government of Kerala and no public hearing has been conducted in Kerala.

(e) The EIA says that the project area is in seismic zone -2 while it is in zone-3. The project's outreach coordinator had repeated this claim in a discussion at the Cochin University for Science and Technology (CUSAT).

INO' Assurances on safety

"This is exactly like making a 2-inch hole to insert a pipe through a 10-foot-high wall. It will not affect the stability of the hill" according to Indumathi, physicist and outreach co-ordinator of INO. "There will be hardly any disturbance after the construction period. During construction, we will take a lot of precautions and proceed in a controlled manner. Controlled blasting of the rock will last a few seconds, twice a day. Answers to questions on the impacts of the project, "such as the effect of the construction on distant dams and the impact of the development on the villagers are outlined in the INO website."[6]

Almost all the main safety issues of INO were summarized in an article published in the journal Current Science[7] and several mainstream publications in English[8], Malayalam and Tamil. These questions have not been answered by the proponents. The main issues are summarized in three parts as given below:

1. The impacts on aquifers of Tunnelling in shear zones – Case studies of hydro-geological impacts of four tunnels - one in Italy, two in India and one from the USA.

2. Critique of the so-called geo-technical study conducted for INO by a geologist from the GSI Chennai.

3. Other miscellaneous issues like the poisoning of groundwater by tunnelling by over 70 chemical compounds which are used profusely during tunnelling for stabilisation and other functions.

Part – I: Tunnelling in shear zones and the aquifer impacts

Dr Indumathi's argument that the controlled blasting will have no impact on the structures of the dams located more than 10 km away from the site is not contested. Our main concerns are the impacts on quantity and quality of the waters in the aquifers and surface water bodies. Tunnelling can rupture underground aquifers and introduce new channels for water to flow. This flowing water will be laden with toxic chemicals used in plenty in the process of tunnelling. These issues have not been addressed by the INO.

The rivers and the dams receive the water stored in aquifers throughout the year. As tunnelling can disrupt the groundwater flows and deplete the aquifers, detailed studies need to be conducted before finalizing such projects. The US Free High Way Authority (US FHWA) says that "rocks with weak planes such as shear zones would clearly indicate a potentially significant seismic risk to a tunnel"[9]. In a paper published in the journal Engineering Geology, Jorge et al warn that "some of the most disastrous experiences in tunnelling have been the result of interception of large flows of water from highly fractured water-saturated rocks. Draw-downs produced by tunnel construction may induce land subsidence, water table decline and environmental impacts on rivers and wetlands"[10].

Of the several documented instances of tunnels disturbing the natural flow of water and causing depletion of groundwater, we will briefly look at four projects. The first one is the Gran Sasso National Laboratory (LNGS) on the Abruzzio Mountain in Italy, currently the biggest underground neutrino laboratory in the world. (INO will be bigger than LNGS.) The second and the third ones – the Rohtang road tunnel in the Himalayas and the Veligonda water tunnel in Andhra Pradesh, are experiencing delays due to 'geological surprises'. The fourth one is the US Armed Forces Special Weapons Command, (AFSWC), where the depletion of aquifer was slow and silent and became visible only decades after construction.

1. The Italian Neutrino Laboratory

The Gran Sasso National Laboratory (LNGS) is located 1,400 meters deep, in the middle of Central Italy's largest massif, in the National Park within a large water-table. At Gran Sasso, the warning by ecologists that the proposed site was close to two major and highly active seismic faults and that the construction would interfere with a major aquifer' was proven true. Paul G. Marinos of the National Technical University of Athens narrates the impact thus: "one of the tunnels came upon a thrust fault with a heavily sheared zone 25 m of thickness. An inrush of 900 litres per second (l/s) lasted for 5 days until the real discharge of the faulted zone occurred with 4,000 l/s–6,000 l/s and a peak of 20,000 l/s (!) filling. Additionally, the tunnel was inundated with more than 30,000 m^3 of debris" (*Ref 7*). After the accident that killed seven workers and flooded the nearby villages, tunnelling was suspended for several months. Even decades after completion of the work, water still leaks from the tunnel walls. According to Abruzzio Social Forum, the rate of drainage is '1500 l/s (or about 50 million m^3 per year)' and the aquifer level dropped from 1600 m MSL in 1968 to 1060 m MSL in 1990"[11].

The flood, loss of human lives and aquifer deformation were only the beginning of a series of Earth events that would shock the Italian Province. It seems that the fault lines that were quiescent for four centuries have been reactivated. According to Bella et al.[12] 'the analysis of the seismicity (M > 3.0) in the Gran Sasso area from 1956 to 1995 suggests that after the tunnelling works, not only has the number of earthquakes increased but the epicentres have migrated, gathering at the NW border zone. The foremost events which occurred in this zone in recent years took place on 5 May 1992 (M 3.1). Tremors continued to rock the region and finally the now infamous L'Aquila earthquake swarms began in November 2008 and culminated in the M 6.3 event of 6 April 2009, which killed 309 people and destroyed several buildings. Until 31 May 2009, more than 6500 events with magnitudes greater than 1.0 with depths between 6 and 20 km were recorded in the region lying between 42.00–42.75°N lat. And 12.75–13.75°E long"[13]

Fermi lab's Symmetry Magazine quotes from a 2005 study by Italian university geologists: "tunnels, although being built for different uses, may drain groundwater even after completion of their lining. In some instances, it is extremely difficult or impracticable to restore the original hydrodynamic equilibrium, with consequent risks of exhaustion of springs, change in the relations with adjacent hydro-geological structures, depletion of groundwater reserves, etc. Tunnel construction also can alter water supply for drinking, irrigation and industrial uses, with major economic and social repercussions on wide neighbouring areas."[14]

2. The Rohtang Tunnel in the Himalayas, India

The construction of 8.8 km long Rohtang Tunnel (3,100 MSL) in Himachal Pradesh, under the Rohtang Pass (3,978 MSL) in the Pir Panjal range of the Himalayas on the Leh-Manali Highway began in June 2010. One of the longest road tunnels in India which will reduce the distance between Manali and Keylong by 60 km, the tunnel is on a route vital for military supplies. The Border Roads Organisation (BRO) of the Indian Army is in charge of the construction based on Austrian technology.[15] According to reports, geotechnical studies were conducted by several agencies[16], none available in the public domain. On 5 June 2012, at 2 km of the tunnel, the boring machine met with a fault line and an underground spring from which a "rivulet gushed out",[17] with an ingress of 3 million litres of water per day.[18] This has slowed the progress of daily excavation from 5 metres to just 0.5 metre and requires 24x7 de-watering".[19] An official of this defence ministry project said that “geological surprises coming one after another” had delayed the project. They are “currently facing high water seepage and loose strata towards Dhundi, 25 km from here”.[20]

3. Veligonda Water Tunnel in Andhra Pradesh, India

The 19.2 km long tunnel NO 2 of Veligonda “is located in sedimentary rock on the western margin of the Cuddapah Basin, where a number of faults and folds make for complex geology. Two major faults are expected along with some ground water”.[21] As of February 2011, on reaching to 3.5 km, the tunnel boring machine bored into an unforeseen area of disturbed geology and got inundated with flowing material. The TBM was stuck for more than a year.[22]

According to the official report “water inflows of up to 9,000 l/min” is “pumped out of the tunnel into the central drainage channel. Another set of pumps is then used to transfer the water from the tunnel portal to separation tanks. Pre-injection grouting is being used extensively to reduce the severity and number of water ingress events.”[23]

4. US Armed Forces Special Weapons Command, (AFSWC)

While in all the three instances above, the water bodies were ruptured during the construction. No such rupture or other calamities was reported during the construction of a special tunnel, the US Armed Forces Special Weapons Command, (AFSWC) in Manzano Mountains. AFSWC was constructed after the World War II, as the emergency relocation centre and as a command post for the US President, but part of the US nuclear arsenal was stored there till 1990. The Manzano Mountains provide 70% of the water recharge for the Estancia Basin and according to one report, "over the last 50 years, well records indicate the depth of the water table has declined by several

hundred feet, with total depletion of the aquifer within as little as 40 years affecting tens of thousands of land owners within an area the size of some small eastern states."[24]

Months after the tunnelling related disasters struck at Rohtang and Nelligonda, BS Acharya of TIFR and 21 eminent high energy physicists wrote in a rejoinder in the Current Science: "Tunnelling is a routine activity in mountains (even in the Himalayas which is the most seismically active region in India or anywhere in the world), under the rivers and seas, and even under mega cities for metro rail transportation. The technology has improved tremendously in the last few decades. It is hard to believe that such an activity can cause major or even minor earthquakes"[25].

PART - II : Geotechnical Study

The criticism "that INO is not transparent, has no basis at all. We have been putting out the details pertaining to the project on our website for more than a decade", said Dr BS Acharya and 21 senior high energy physicists. However, the "Geotechnical Study Report" for INO is still a confidential document.

Seismicity was an important criterion for INO's site selection as "it is a crucial ingredient for the design and stability of the underground detector as well as all surface facilities at the site".[26] As per the Bureau of Indian Standards, Theni district and also all districts of Kerala are in seismic zone 3.[27] According to the Rapid EIA for INO done by the Salim Ali Centre for Ornithology and Natural History (SACON), "the project location is *reported to be* situated in Seismic Zone 2."[28.] Prof Indumathi, the outreach coordinator of INO told the students of physics at the Cochin University for Science and Technology (CUSAT) on October 19, 2012 that "the INO site is in seismic zone 2, the lowest in India, and hence there is no room for any concern regarding tremors."[29] INO's FAQ [English] has a question "what happens when there is an earthquake or rock burst"?[30] The original answer, that it is located in zone 2 has been removed in March 2013, the question is still there as a dead link. On the issue of seismicity, the FAQ in Malayalam says that a cave is the safest place during an earth-quake.[31]

Before submitting a big underground tunnel project, a detailed geo-technical study, which will take a closer look at the ground water and possible hurdles like geological faults which will hamper the tunnelling work. This is much like an environmental impact assessment for surface-based projects. A geologist of the Geological Survey of India prepared a report after visiting the portal area of the project for 5 days. The report does not contain a word on the water bodies. This report is kept as confidential and is not in the public domain. The US Free High Way Authority (US FHWA) says

that "for a road tunnel through mountainous terrain the high cost, lengthy duration, limited access, and limited coverage of field investigations may demand that investigations be carried out in several phases to obtain the information necessary at each stage of the project in a more cost-efficient manner. The cost of a complete GTS for a road tunnel projects is typically about 3% to 5% of construction cost".[32] The cost of INO being Rs 1300 crores, a proper GTS would have cost about Rs 40 to 60 crores. INO GTS was done by one geologist who worked for 5 field-days, and was based on four bore holes data, all from near the portal area. The geotechnologist did not visit the land above the cavern area. The report does not way a word about the aquifer and dams.

The Quality of data

1. "Only portal area and initial reaches of the access tunnel alignment were studied because, rest of the reach is not accessible as the hill is too steep. Hence, the remaining reaches of the access tunnel up to the hill peak were *observed only from a distance*". (Emphasis ours)

2. "The rock outcrops at the eastern side of lower slopes were only examined and the observations are extrapolated to higher reaches due to limited access."

3. Quality of the bore-hole samples:

[a] “the cores were not arranged run-wise".

[b] "no depth marking was done for each run; only a cumulative depth for certain runs given".

[c] "many samples did not have arrow marking indicating the direction of depth".

[d] "driller's log sheet doesn’t indicate water loss or water colour details."

4. "The observations made in rocky slope between the borehole No 4A and the first vertical cliff showed the presence of weathered granite gneiss. Two additional bore holes were recommended to know whether the weak rock is persisting at depth as the weathering pattern is seen to be irregular in the study area. The project authorities informed that *they could not obtain forest department clearance to drill these bore holes*."

5. "This has resulted in the *approximate fixin*g of weathered rock and fresh rock levels".

Observations of the Geologist

1. "The profuse intrusion of granite with closely spaced sub-horizontal joints probably along the margin of Suruliyar -Kambam shear zone is the rock characterisation in the portal area of access tunnel alignment."

2. "The regional geological map shows a shear zone trending NNE-SSW and traversing access tunnel in middle reaches."

3. "The only concern would the >1000 m of rock cover which would create stress related problems like rock bursts".

4. "The study has revealed that fresh rock is not available at uniform depth in the holes. There is a sudden variation in the rock level between bore hole 4 and 4a (higher at 4A) and there is a fall in the rock level to a depth of 27.41 m within 45 m distance"

5. "Second generation geological maps prepared by GSI shows the presence of faults. In view of these observations, it is prudent that seismic coefficients for Magnitude 5 earthquakes are provided while designing the detector in the lab cavern".

Our comments

1. Land above the caverns not studied

The laboratories are located at the end of the 2100 m long tunnel. It may be impossible for people without mountaineering skills to climb the steep hill. But they could still go to 1589 peak above the proposed caverns [under which 60% of the blasting will be done] by road via village Shantanpara in Kerala.

2. Low quality drill data

The major component of the study is analysis and characterisation of the drilled samples, the other components being visual observations and literature survey. The drilling was not done professionally and two subsequent drilling ordered was not done as they could not obtain the permission from the forest department! As the author himself says, the main part of the geo-technical study is an approximation.

3. Underplaying the shear zone

The GTR underplays the shear zone. In plate No-5, [page 20], both the shear zone and the tunnel are shown as single lines and they look like two roads intersecting each other in an acute angle. In fact, the caverns and the tunnel are located in the middle of the shear zone which is 10 km wide (see discussion and map below).

4. Rock-bursts and their unpredictable effects

The warning in the GTS that blasting under "*>1000 m of rock cover which would create stress related problems like rock bursts*" was ignored by the

At the proposed site, about 80% of the blasting will be under an overburden of 1000 m or above.

PART – III: Tunnelling Chemicals and groundwater toxicity

We saw that the tunnel in the Italian neutrino laboratory is conveying millions of litres of water from the ruptured aquifers to the Vomano River. According to LNGS, "the collected waters, which are not drinkable, are conveyed through several collecting points to another underground circuit called "dripping water circuit". In order to ensure that the contamination does not kill the Vomano river, "Special analysis devices measure Total Organic Carbon (TOC), conductibility, pH and turbidity, continuously monitor water in the sump pit. The TOC analyzer can detect a variation of 0,5 mg./l. in the waters' organic contents, that is the introduction of 1 mg./sec. of any substance considering the maximum discharge."[33]

The water draining out from LNGS tunnel is not drinkable because massive amounts of chemical compounds are used in tunnelling as strengtheners and stabilizers. One Dutch company that manufactures tunnel-related products lists 77 chemical compounds which include rigid, flexible, semi-flexible, water activated and silicate / polyurethane hybrids, polyurethane grouts etc. It is not known if any of these have been tested for safety[34].

According to the company spokesperson "this project area receives more than 3000mm rainfall annually, excavation will be very challenging and need of shot-creting based on class of rock and strata, definitely required more thickness of concreting. Currently several of our concrete spray machines are used in underground mines" in India.[35]

DISCUSSION

Birdwatchers and neutrino gazers replacing geologists

In India, seismic zoning is done by the Bureau of Indian Standards based on the consensus judgments of geologists and scientists in related fields. Here, for the first time the ornithologists have changed the seismic grading of district Theni from 3 to 2. A high energy physicist and INO's outreach co-ordinator, uses this fabricated data to get its public acceptance. The Central Ministry of Environment and Forests accords sanction to the project without checking the facts. And finally the Union cabinet approves the project, two years after these gaps and holes were published in a peer reviewed science journal.

Holton's self-fulfilling prophecy?

Acharya et al's UNCONDITIONAL faith in technology reminds us of the physicist-philosopher, Gerald Holton's prophetic words during a lecture in Kashmir, in 1970 that "the 19th-century faith that science will show the way to the solution of all problems and lead us soon to Utopia was a tragically naive illusion." Were Holton's words that "science and its technological offspring must come under the control of an anthropocentric ethic if human is to survive"[36] a self-fulfilling prophecy? Four decades down the line, eminent scientists and philosophers from the Oxford and the Cambridge universities are discussing the "global catastrophic risk" (GCR) and "existential risk" (ER) from biotechnology, geo-engineering, nanotechnology and artificial intelligence.[37]

Conclusion

The annual loss of water due to the Italian neutrino lab discussed above is about 15% of the total active storage in Mullaperiyar dam. The depletion of groundwater in Italy during 22 years since the construction of the laboratory is 540 meters! What will be the impact of a depletion of 5 meters, (<1% of 540 m) on the livelihood of people in the region dependent on Idukki-Theni aquifers? Unlike a road or rail tunnel or mine, there is no compelling reason for INO to be located in its proposed site, in a sheer zone with rich water bodies that are the life line of over 5 million people. Major neutrino observatories and underground laboratories in the world are located in used mines, ocean beds, lake or ice sheet. LNGS, the only one, located on a mountain range with a horizontal access has been a perfect ecological disaster. INO's only reason to hang on to the present site is the government's sanction obtained using fabricated data, without undertaking a proper, scientific risk analysis, and bypassing the established procedures of public consultation with all the stakeholders.

The decision of Ministry of Environment and Forests to sanction to the project, was a political one, and was not based on credible scientific data.

Acknowledgement

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