Mountain tunnelling, aquifer and tectonics – a case study of Gran Sasso and its implications for the India-based Neutrino Observatory by V. T. Padmanabhan and Joseph Makkolil – a critique

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The opinion article by Padmanabhan and Makkolil[1] though written in a lucid manner contains factual inaccuracies, conceptual deficiencies and compares an apple with an orange. Although people have every right to entertain a different opinion and can seek answers for their legitimate queries, providing misleading information should not be resorted to as such acts can lead to irreparable damage. Scientific objections should be raised only with factual data to the contrary.

It has been emphatically mentioned that 'No geotechnical study has been conducted for this project'. Nothing can be farther from the truth. The Geological Survey of India (GSI) has conducted geotechnical studies of the present India-based Neutrino Observatory (INO) project site in Theni district and also its alternative sites to help zero in on the best possible site (GSI, unpublished). The results of investigations are provided in a report dated December 2010. An exhaustive Detailed Project Report (DPR) has been prepared by Tamil Nadu Electricity Board and duly approved by competent authorities. It is painful to note that the authors[1] are totally unaware of this report and the information contained in it and chose to disseminate misinformation instead.

The very first sentence in the abstract[1] mentions that 'INO is about to construct an underground laboratory in the Western Ghats within the Idukki–Theni charnokite aquifer'. The Idukki–Theni charnokite aquifer (ITCA) is a nomenclature proposed by the authors. Charnockite is not an aquifer but a rock mass and in most of this area it is massive with very little weathering. Expression of charnockite as an aquifer is used with the intent of misleading people to believe that the entire hill mass is charged with water, whereas factually in most places at depth the rock is bone dry. Several boreholes drilled in the area can vouch for this.

An aquifer can be defined as 'an underground layer of permeable rock, sediments (usually sand, gravel) or soil that yields water. The pore spaces in the aquifer are filled with water and are interconnected so that water flows through them. Sandstone, unconsolidated gravel and porous limestone make the best aquifers. They can range from a few square kilometres to thousands of square kilometres in size'. On the contrary, charnockite is a rock mass which cannot transmit water unless it is fractured by joints or riddled by fissures/faults, intrusions, etc. The degree of fracturing/joints varies from area to area. In any hard rock which is not pervious, the porosity is secondary and therefore it is not qualified to be defined as an aquifer. Charnockite can be classified as an aquitard which can be defined as a 'medium that may contain groundwater but not capable of transmitting significant quantities of it under normal hydraulic gradient'. Secondly, the entire area is not made up of charnockite only and there are other rock types such as quartzo-felspathic gneisses, other gneisses, carbonatites, pyroxene granulites, etc. The head race tunnel of Idukki dam, semi-underground power house at Moolamuttom and several other tunnels located in Idukki district are driven through charnockite rock in majority of the reaches and they have not led to depletion of groundwater or led to catastrophes in the nearly last four decades of their existence.

People associated with rock tunnelling the world over carry out detailed hydrological surveys wherever necessary to take precautions of preventing heavy water inflow into the tunnel leading to damages and litigation, and to avoid environmental damage. GSI studies in the proposed INO site in Theni district have shown that along the access tunnel alignment and in the cavern area there is no abnormal threat of groundwater influx. This combined with the fact that no habitation or water wells exist in the proposed site, there is little danger of groundwater regime being disturbed by the proposed tunneling.

Aquifer and surface water bodies charging the river system in any place are known as *effluent seepage* whereas the rivers and surface water bodies charging the aquifers or charging the fractured rocks are known as *influent seepage*. The process that is taking place in the ITCA area mentioned by the authors[1] is influent seepage so the statement that 'this aquifer and the surface water bodies feed three river systems – Periyar, Vaippar and Vaigai' is totally erroneous and needs thorough revision. By citing various man-made reservoirs, including Idukki and connecting them to INO indirectly or directly is outrightly an unscientific portrayal of the project. The mean and flood discharges of all the rivers in the area are solely due to precipitation by rainfall and effluent seepage in the area is not reported in significant proportion so far. So the project does not challenge the stake of livelihood of the people in the region nor cause any harm to the environment by any stretch of imagination.

The quote[1] in the section 'Aquifer characteristics' regarding warning by mapping report of TN is also out of place. The INO project area lies in a hilly terrain which comprises hard rocks, as shown by a CGWB report[2]. The report[2] also mentions that depth to water level in the valley portion (not in the hills) such as Bodinayakkanur, Chinnamanur, Uttamapalayam, etc. varies from 2 to 10 m. The over-exploited areas listed in the report include Andipatti, Chinnamanur, Periyakulam and Uttamapalayam. All these areas fall in a different hydrological milieu and in plains where water draft for agricultural purposes is immense, leading to criticality and super-criticality. The classification of areas as 'critical' by CGWB denotes regions in which draft of groundwater is in a dynamic threshold; by over drafting it can be rendered super-critical and with proper groundwater management/artificial recharging it can be rendered sub-critical. By juxtaposing two radically different regimes of groundwater, an illusion is being created about the proposed INO project, as if it is detrimental to the environment and local populace.

The authors[1] have also misunderstood the quote of Rajendran *et al.*[3]. The meaning of the quote is that Idukki area was prone to the occurrence of earthquakes even before the construction of the Idukki reservoir, a fact which does not support reservoir-induced seismicity or reservoir triggered seismicity as it is now called. Extensive field surveys and analysing loading/unloading data of Idukki reservoir for a protracted period by the present author have shown that the earthquake at Nedunkantum in 1988 was due to crustal adjustments along lineament(s) and not triggered by the Idukki reservoir. It is well known that Idukki area is mildly seismically active, with most being microseismic events which can only be instrumentally recorded. Only very few are felt by humans.

The connection implied by the authors between the L'Aquila earthquake of 6 April 2009 and Gran Sasso Project is illusory and they are not connected. Details of this earthquake indicate a momentum magnitude 6.3 whose focal depth was 9.46 km – a shallow earthquake being the major reason for such huge losses. The area is also known for its extensional tectonics and historically known to be earthquake-prone. Also, the city of L'Aquila is founded on loose lake sediments and the reports have suggested that the buildings/construction material standards are poor, thus also contributing to such losses. The causative factor reported for the earthquake is movement along a NW–SE normal fault, as a number of NW–SE active faults are present in the area and it is therefore amply clear that there is no link between the incident and excavation of Gran Sasso Project components; the earthquake was caused by a different mechanism. No report other than by these authors[1] has linked this earthquake to the presence of Gran Sasso laboratory.

Changes in hydrological regime after major earthquakes are established facts world over, but that has got nothing to do with excavation of Gran Sasso facility because the causative factor for the L'Aquila earthquake was the activation of NW–SE normal fault. So listing out all the changes in hydrological regime in the instant case is needless and irrelevant. Similarly, recording of swarms of foreshocks and aftershocks of a main event is normal in many major earthquakes. They denote only dissipation/build-up of stresses versus time and are studied for an entirely different purpose. Calling attention to these and drawing undue and out-of-place inferences are totally unsolicited and unwarranted.

The Gran Sasso Project area is occupied by limestone that too with karst features of caverns, grykes, etc. in contrast to Theni area which is made up of massive charnockite/gneisses. The karst features of limestone country are due to water and water action where solution channels, tunnels and caverns filled with water can be encountered at depth and can burst during tunnelling. Also, two faults were reported to have been crossed by the main tunnel and they might have acted as water barriers and trapped water. The hilly terrain of Theni is composed of rocks devoid of water, particularly along the proposed tunnel alignment. No huge water reservoirs as imagined by the authors exist or are known inside the hill mass, so that the imaginary depletion can lead to catastrophe. Gran Sasso area is located in a tectonically active zone. On the contrary, the proposed INO at Theni is located in a stable continental region (SCR). The geological milieus of Gran Sasso and Theni area are as different as chalk and cheese.

In the section 'Seismicity during construction' several issues are mixed up. Kolar excavations and the consequential rock bursts are stress-related phenomena. They have nothing to do with drilling and blasting, method of excavation or tectonic earthquakes. To forewarn the occurrence of rock bursts instrumental monitoring is done. The rock bursts are similar to earthquakes in wave propagation and occur in high-stress areas where horizontal stresses far exceed the vertical stresses. Kolar rocks are predominantly made up of schists, which leads to delayed bursts as indicated by research. Currently, many large diameter tunnels are being constructed in the Himalayan region where rock bursts occur frequently and the problems are being surmounted. This phenomenon is normally taken as tunnelling hazard and not an environmental hazard, as little or no damage has been caused to the environment. The first-level studies at INO indicate no rock stress problem in view of better correlation with calculation of horizontal stresses with the competency of the tunnelling media (compressive strength) and also due to absence of high tectonic stresses as in the Himalayas. In the extraordinarily remote and the unlikely event of encountering such high-stress problems, instrumentation and monitoring of the bores concurrently with the excavation are planned to obtain advance information and different tunnelling techniques can be employed to mitigate such problems.

Tunnels are excavated by many ways such as using pneumatic/hydraulic hammers, excavators, road headers and the most commonly used method, i.e. drilling + blasting method or by tunnel boring machines (TBMs), etc. All these methods depend on performance, based on the strength of rock mass media, length of the tunnel, water inflow, abrasiveness of the rock and other techno-economic factors. TBMs cannot be employed everywhere for techno-economic reasons. Over the years methods of blasting have improved by leaps and bounds, and therefore, the effects of vibrations can be minimized. Vibrations, which are temporary in nature, become a critical factor mainly in areas of habitation and not in a remote and far-flung site such as INO, Theni, where its effect on the environment will be insignificant. As apprehended, they will not cause any damage to closeby landscape or to geological formation. This can occur only in the extreme case of blowout, where the vertical cover is made up of poor-strength material and the cover is thin. In case of the proposed INO at Theni, unlimited good quality cover over the crown of the tunnels is available.

There is absolutely no lack of transparency, because geotechnical investigation of the site have been carried out by the Government of India Department. The project authorities have conducted many mass contact programmes, public hearings, etc. and there is no need to be clandestine about the construction of the project. The sweeping usage of regular jargon of fragile Western Ghats for each and every venture should have been avoided, as execution of this project at a depth of more than a kilometre in a controlled manner, is not going to increase its fragility. What is the need of the hour is an objective assessment and not sweeping generalization.

The conclusion section reiterates that the facility should not be at this site. It is projected or implied that having the facility at this location can cause a great and imminent danger to the local populace and environment. The authors should explicitly state what their genuine apprehensions are if the project is located here. The reasons such as construction of the project can cause earthquake, will drain a charnockite aquifer and disturb the fragile environment of Western Ghats are figment of imagination and will not hold water from scientific consideration.

Only after a rigorous analysis and exhaustion of all alternatives, the current site has been chosen. The crux of the problem appears that INO site cannot be at Theni, but can be anywhere in the country.

1. Padmanabhan, V. T. and Makkolil, J., *Curr. Sci.*, 2013, **104**, 414–416.
2. Central Groundwater Board, *District Groundwater Brochure*, Theni District, Tamil Nadu, http://cgwb.gov.inDistrict_Profile/Tamilnadu/Theni
3. Rajendran, K. *et al.*, *Curr. Sci.*, 2012, **102**, 1446–1451.

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