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I am a radiologist with 35 years of experience working for several hospitals in Sydney. I am interested in radiation effects *because when the Australian government decided to relocate low waste nuclear material from Mount Druit in Sydney there were three health workers who were all in the first trimester of pregnancy who subsequently had children with major heart defects, which I considered to be due to the stochastic effects of low dose radiation*.

My interest in the Lynas issue has also been developed over the years through my husband and his Malaysian friends who often discuss about Lynas with us since it is an Australian company and I have in-depth professional knowledge in radiological issues.

We are both genuinely concerned when we first read from the media how an Australian mining company Lynas has located a rare earth processing plant in the coastal region near the pretty city of Kuantan. My husband has visited Kuantan several times. He simply loved the peaceful, clean and well lay-out city and its ever welcoming friendly and warm local people.

Recently, we have been informed that over 1 million cubic metres of radioactive waste will be sent to a disposal facility to be carved out of a relatively intact rainforest some 30 km from Kuantan. I decided to check it out and saw that Lynas has submitted an environmental impact assessment report and is seeking public review feedback.

As a radiologist, I work with radiation all the time and I am trained to manage exposure doses for patients and the safe disposal of contaminated waste materials. Safety is prioritised in my profession. I hope I can constructively contribute to the debate in Malaysia so that the public and the government are better informed on radiation safety issues.

Given the limited time for public consultation – where access is only allowed to **view** 11 chapters of technical reports plus appendices etc, my comments below are based on the Executive Summary and sections in Chapter 7 on the radiological issues and several other sections of some of the other chapters eg Chapter 8 and 11.

Issues of Concern

The EIA has mainly been focusing on projecting an overly optimistic scenario to justify the proposal. There needs to be a comprehensive health impact study carried out by an independent agency. From my review of the Lynas environmental impact assessment documents, several issues have caught my attention:

No Safe Dose of Ionising Radiation

Based on the EIA Ch 7.14.1:

> WLP residue contains NORM of ^{238}U and ^{232}Th and their progenies which makes up the characteristic of a very low-level waste (VLLW) based on the IAEA guideline. The average activity concentrations of ^{238}U and ^{232}Th were found to be 6.3 ± 0.4 Bq/g and 0.33 ± 0.07 Bq/g respectively whereas their respective radium daughters; ^{226}Ra and ^{228}Ra, contain average activity concentrations of 6.5 ± 1.0 Bq/g and 0.55 ± 0.06 Bq/g respectively.

Thorium and uranium are both radionuclides with extremely long half-life – 14 and 4 billion years, respectively. While these radionuclides are found naturally in soil and rocks, known as naturally occurring radioactive materials (NORM), those found in Lynas' waste streams have been concentrated through industrial processes and are technically enhanced (TE). They are, by definition, known as TENORM[1].

According to the US EPA,
'"Technologically enhanced" means that the radiological, physical, and chemical properties of the radioactive material have been concentrated or further altered by having been processed, or beneficiated, or disturbed in a way that increases the potential for human and/or environmental exposures. '

The rare earth industry has been identified with associated problems of NORM and TENORM management due to the large quantities of residue and wastes produced through its processes[i]. Through harsh industrial processes, the equilibrium in the decay series of TENORM might have been disturbed and breaks could occur at radionuclide with a long half-life[2].

Lynas' NORM/TENORM are now exposed in its waste streams. For the WLP residue, leaching can occur especially from the intrusion of rainwater through its acidic 'gypsum waste. Th and U are both sources of ionising radiation as

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[1]https://www.epa.gov/radiation/tenorm-rare-earths-mining-wastes – US EPA's Radiation Protection Guide on TENORM : Processing rare earth minerals involves the separation and removal of uranium and thorium, which results in TENORM wastes

[2]*Radiation Protection* in *NORM* Industries. IRPA 11 Refresher Course 5A. 27 May 2004. Madrid. J. van der Steen, A.W. van Weers. NRG, Arnhem, powerpoint presentation

they are both alpha emitters and **there is no 'safe' dose of this form of radiation**[3]. *Radiation of all types cause genetic mutations and eventually cancer develops through stochastic and non-stochastic effects. Non stochastic effects are dose dependent. Stochastic effects are due to the chance occurrence of a radiation beam hitting a molecule.*

While the stochastic effects increase with the amount of radiation ***there is no threshold dose below which these effects will occur.*** There is no safe dose of radiation. **The primary concern for radiation safety and protection is therefore to contain them to prevent any exposure to the biosphere**.

I have attached with my submission a valuable factsheet prepared by a GP from the Medical Association for Prevention of War (Australia) and the Nobel Prize recipient, International Campaign to Abolish Nuclear Weapons (ICAN) to help further Malaysian Government's understanding of the hazards and risk associated with Lynas' WLP residue, and to take the necessary precaution to protect public and environmental health.

Wet Climate and Soil Erosion

The wet tropical climate in Malaysia with frequent floods during the monsoon period is likely to expose the waste to harsh weathering, potentially exposing the radioactive materials further than the waste storage facility. I noted the mitigation measures proposed in Ch 8. My concern is whether such mitigation efforts – which are rather ordinary like better drainage - are adequate for a massive waste facility?

My husband who frequently visit Malaysia informs me that road conditions are often bad in rural area, including high speed freeways due to severe/extreme weathering factors, even though there has been good drainage built in. Further, landslides and soil erosion are quite common during and after the annual monsoon deluges. The instability in the environment adds to the risk and hazards of locating a radioactive waste storage facility in the proposed site.

Proper Public Consultation and Informed Consent

Given the massive volume of the WLP residue, this will not be a simple task. Full public consultation and engagement are required, considering the potential impacts should the proposed PDF fails to contain the radionuclides and they contaminate the water supply of Kuantan and/or the natural environment. Residents depending on the catchment for their water supply have not benefitted

[3] See also "Radiation and Health" factsheet 12 by Dr Bill Williams

from the Lynas venture. They have been unfairly impacted indirectly and soon may be directly, when and if their water supply is contaminated. The short consultation period and the limited access granted to members of the public to effectively review the technical EIA is grossly inadequate, inappropriate, and unfair, to say the least.

Classification of the WLP Residue

The classification as a VLLW has been challenged by other experts[4] from what I have been shown, and that the appropriate classification should be LLW – low level waste under the IAEA Guidelines, which require more stringent disposal management, especially in light of the presence of significant amounts of long living Th and U in the mix.

I noted the Radiological Impact Assessment (RIA) presented in Ch 7 from page 195/219. I am surprised that the RIA is so brief for a large radioactive waste repository in a wet tropical environment where governance can leave much to be desire. A proper RIA for a project of this scale and size, should be carried out and the findings made accessible to the public over a longer period for input and feedback.

Optimistic Assumptions in Exposure Dose Modelling and Accidental Release

In Chapter 7, optimistic assumptions were made in the modelling of exposure doses, for example:

> **Onsite Radiation Exposure during Post-Closure Stage**
>
> Calculations for the post-closure stage were performed for a period of 1,000 years with the other parameters from the operational stage being retained. In the calculation, it was assumed there would be no erosion of the cover. The findings are summarised in **Table 7.14.15** below.

As we know, excessive radioactive exposure often occurs accidentally or through problems yet to be factored in during the design phase of the facility. However, there has not been detailed study of the possibility that the PDF may fail to contain the radionuclides – especially say in 50 years' or 100 years' time, or truck accident during the transportation stage of the proposal. **The over optimistic assumptions made in the EIA are unrealistic and should be questioned**.

[4] I have read the court statement by Melbourne nuclear medicine specialist Dr Peter Karamoskos and the critical review of the Malaysian Atomic Energy Licensing Board (AELB) guidelines for NORM management by Germany's Gerhard Schmidt.

This is particularly critical when considering the LONG-term (in the hundreds of thousands of years) when the structure of the PDF may be weakened and damaged given the weathering effects from rain in the wet tropic. Modelling based on everything working well is flawed and the results cannot be interpreted as those representing the reality.

7.14.4.1 Estimated Dose Received by Workers During WLP Handling & Transportation

Exposure from External Radiation

In estimating the exposure of workers to WLP, the external radiation levels measured at the WLP RSF in LAMP will be used since the operations at the PDF later would involve the handling of the same WLP residues. The external radiation data was extracted from the ERMP between 2014 to September 2019 (**Figure 7.14.1**) and included in **Table 7.14.3**

Table 7.14.3: External Radiation Levels on the Truck Carrying WLP (2017 – 2020)

Distance from container surface (m)	External radiation level (µSv/hour)		
	Min	Max	Ave ± Std Dev.
0.01	1.2	2.90	1.83 ± 0.05
1.0	0.37	1.10	0.69 ± 0.05
2.0	0.09	0.27	0.19 ± 0.04

Note: Background external radiation measurements range from 0.09 to 0.36 µSv/hour, with the average of 0.26 ± 0.07 µSv/hour

Exposure during the transportation of WLP will be determined based on the averaged external radiation data obtained from the transportation of lanthanide concentrate due to the similar external radiation levels recorded for the two (2) substances. The exposure rate for the truck drivers will be calculated at a distance of 2 m due to the gap between the drivers and the containers. The annual external radiation dose was calculated using the formula below:

Annual Radiation Exposure (mSv/year) = [(**MR** – **BG**) x ***t***] / 1000

Where:

MR is measured dose rate (µSv/hr);
BG is background dose rate (µSv/hr);
t is total exposure time (hours per year)

In estimating the annual nett dose, it was assumed that the average external radiation level (**Table 7.14.4**) of 1.57 µSv/hour exposure (WLP RSF) is consistent throughout the 2,000 hours/year exposure, which results in an annual nett dose of 3.14 mSv/year. It is to be noted that the annual nett dose is excluding the natural background radiation.

Table 7.14.4: External Annual Nett Dose Received from External Radiation

Activity	Critical group	Ave. external radiation	Exposure (hr/yr)	Estimated annual nett dose (mSV/yr)
LAMP: Loading of WLP into trucks	On-site workers	1.57 ± 0.76	2,000*	2.74
Transport from LAMP to PDF	Truck drivers	NIL		NIL
Unloading of WLP into PDF	On-site workers	1.57 ± 0.76		2.74

Note: 1. AELB Limit (BSRP, 2010): Radiation workers: 20 mSv/yr – equivalent to 10 µSv/hr; MoP: 1 mSv/yr equivalent to 0.5 µSv/hr
*2. *if the worker is to work on the WLP for 2000 hours/year ie a constant 40 hours per week for 50 weeks.*
3. NIL signifies no exposure from the WLP residues

The assumption that there will not be erosion of the cover should be questioned especially considering predictions by climate scientists of extreme monsoonal storms in a climate change scenario[5] and in light of the Malaysian experience where rain often causes structural damages to buildings.

Another example of justification without evidence is as follow:

8.14 RADIATION & RADIOACTIVITY

The WLP disposal method adopts world-class standards for its environmental performance. To prevent or limit the consequences of accidental releases to the environment, each stage of the PDF development plan will be subjected to hazard and operability analysis, including details of safety hazards, implications of failure of equipment or mal-operation, correct operating parameters, precautions to be taken and contingency plans in the event of accidents.

These are statements made without modelling data and are unacceptable since the proposal is for a mega radioactive waste dump in a populated developing country like Malaysia.

Linear No-threshold Approach to Radiation Safety and Protection

The emphasis from the EIA in Ch 7 on exposure dose seemed to have focused on external dose, when in the case of the NORM/TENORM in Lynas' WLP residue, the risk and hazards from ionising radiation from inhaling and ingesting fine particles contaminated with Th and/or U should be examined in greater depth.

Firstly, from the radiation safety and protection point of view, the linear no-threshold (LNT) approach has been the standard used in radiation safety all over the world by responsible governments. This approach is based on the US National Academy of Science (NAS) through its decades of research on cancer deaths linked to radiation exposure of different doses. Since 2006, its Biological effects from ionising radiation advisory series VII (BEIR VII) has provided "the most up-to-date and comprehensive risk estimates for cancer and other health effects from exposure to low-level ionizing radiation. It is among the first reports of its kind to include detailed estimates for cancer incidence in addition to cancer mortality. …"

"A comprehensive review of available biological and biophysical data supports a "linear-no-threshold" (LNT) risk model—that the risk of cancer proceeds in a

[5] https://www.sciencedirect.com/science/article/pii/S167498711400036X

linear fashion at lower doses without a threshold and that the smallest dose has the potential to cause a small increase in risk to humans. The BEIR VII report defines low doses as those in the range of near zero up to about 100 mSv. It is important to bear in mind **that radiation exposure doses add up over a lifetime**. Therefore, every effort is required to minimise exposure to the bare minimum and to as close as possible to the background level which we cannot control.

Ionising Radiation and Cancer Deaths

https://www.bmj.com/content/351/bmj.h5359

In this cohort study, 308 297 workers in the nuclear industry from France, the United Kingdom, and the United States with detailed monitoring data for external exposure to ionising radiation were linked to death registries. It provides a direct estimate of the association between protracted low dose exposure to ionising radiation and solid cancer mortality.

The LNT model has been backed up with this 2015 large cohort study of workers and informed the International Commission for Radiological Protection (ICRP) of the need for greater safeguards for workers and people exposed to this kind of radiation. The LNT model was first recommended by the US National Academy of Science and is now adopted by established international bodies such as the International Commission for Radiological Protection, UNCEAR, IAEA and WHO, just to name a few.

https://www.nrc.gov/materials/srcmaterial.html

The US Government through its Environment Protection Agency (EPA) has imposed a stringent 0.05% threshold on thorium or uranium content on radioactive source materials. Due to its long half-life, thorium source material. It is my understanding that Lynas' Th concentration is about 4 times that at 1600ppm – 1952ppm.

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[i] https://www.epa.gov/radiation/tenorm-rare-earths-mining-wastes