Comments on the 'Proposal for a Permanent Disposal Facility for Waste Leach Purification (WLP) Residue at Bukit Ketam Mukim Kuala Kuantan, Daerah Kuantan, Pahang Darul Makmur' by Lynas Malaysia Sdn. Bhd.

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Synopsis

We provide independent expert comments on key issues of concern regarding the proposal for a permanent disposal facility ('PDF') for radioactive residues from the Lynas Advanced Materials Plant ('LAMP') in the Gebeng Industrial Estate near Kuantan, Malaysia. This has been requested by representatives of the local community in the Kuantan region as part of independent expert comments on the environmental impact assessment (EIA) documentation published by Lynas and being reviewed by the Department of Environment in Malaysia. Due to the very limited time available for this review and the lack of access to the full documentation and references cited therein, our comments are focussed on the principal engineering design adopted and associated environmental aspects such as water quality, hydrology and climate change risks.

We believe there are serious flaws and weaknesses in the proposed WLP PDF which point to the need for much greater emphasis on baseline studies, engineering design and environmental monitoring and long-term site stewardship. The current EIA does not address these aspects sufficiently, especially given the long-lived nature of the radioactivity contained in the WLP residue (i.e. thorium and uranium), leading to the need for considerable further investigations and re-design of the PDF – or the pursuit of alternatives which could be more technically suitable and environmentally preferable.

Material Reviewed

The PDF EIA has online links for viewing only – it was not possible to download the files for local review and use[2]. This is a completely impractical manner in which to view such complex scientific studies; online only through an internet browser. As such, we have relied on the following key sections of the EIA (details for verification from the website):

- *Executive Summary*, folder "1. Intro", file "10. Lynas Executive Summary.pdf"
- *Project Description*, folder "2. Body", file "AGV-MY-R37-0221-CHAP5-FINAL.pdf"

We would welcome the opportunity to receive full access to the EIA files and documentation – and an appropriate amount of time to thoroughly review all aspects of the PDF EIA, including cross-reference and comparison of key safety guides and codes for wastes such as the WLP residues.

[1] Our comments are provided as independent academic experts with no conflict of interest and do not represent the views of anyone else or other organisation (including RMIT University).

[2] The official Malaysian Department of Environment online site for the EIA files is (Accessed 18 March 2021): https://drive.google.com/drive/folders/1cCLd1AsCko0zTKAeKZcFJX7-WDy1I48U

Waste Classification

The EIA presents the classification of WLP residue as 'very low level waste' (or VLLW), based on the IAEA's 'Classification of Radioactive Waste' general safety guide (IAEA, 2009). The full definition of VLLW from this safety guide is:

> *"Very low level waste (VLLW): Waste that does not necessarily meet the criteria of EW[3], but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low levels of activity concentration.* ***Concentrations of longer lived radionuclides in VLLW are generally very limited.****" (page 5, IAEA, 2009)* *(emphasis on last sentence added).*

As noted above, the crucial part of the justification of classifying a waste as VLLW is the very limited concentrations of long-lived radionuclides – such as thorium and uranium. The WLP residue clearly has environmentally and radiologically significant concentrations of thorium and uranium, demonstrating that it should not be classified as VLLW but instead as low level waste (LLW) which requires isolation for considerable time periods of up to several centuries or longer (see IAEA, 2009).

To assess this more quantitatively, we compare the average concentrations of uranium and thorium in upper crustal rocks with those of the Kuantan area, WLP residues and criteria for VLLW, see Table 1 below (with data presented in mass concentration and equivalent radionuclide activity units).

Table 1: Comparison of concentrations and activity[A] of uranium and thorium in various media

Source Material	Uranium[B]		Thorium[C]		Reference
	mg/kg	Bq/g	mg/kg	Bq/g	
Average Upper Crustal Abundance	2.7	0.035	10.5	0.0425	Rudnick & Gao (2014)
Gebeng Industrial Estate Soils (mean)	~3.0	0.0369[D]	~14.4	0.0582[D]	Mei-Wo *et al* (2015)
WLP Residue	22.5	~0.276	1,655	**~6.7**	Page 5-17, EIA Chap. 5
Very Low Level Waste Criteria	**~82**	**1**	**~250**	**1**	Page 5-17, EIA Chap. 5

Notes: [A]Radionuclide activity calculated from mass concentration using the approach in Langmuir (1997), hence some values are approximate (~) only; [B]Uranium activity includes U^{238} and U^{235}; [C]Thorium activity represents Th^{232} only; [D]Represents U^{238} activity only (noting that U^{238} is ~99.3% of natural uranium by weight or ~96.5% by radioactivity).

On the basis of the data in Table 1, the WLP residue should be classified as low level waste due to the very high concentrations of thorium present and certainly not VLLW. The EIA argues that the distinction is typically based on radon flux, which is easily reduced for thorium-dominant wastes. Specifically, it is argued that "1 cm of clay (or equivalent) is sufficient to completely stop radon flux" (page 5-18), thereby justifying the adjusted classification of WLP residue as VLLW. However, there is virtually no confidence that such a thin cover could be maintained in perpetuity, especially in a tropical climatic context such as the Gebeng-Kuantan region – for example, erosion could affect the integrity of the engineered cover system over centuries to millennia.

Furthermore, the safety cases in many nations assume that institutional controls on radioactive waste facilities will be effective for a period of up to 300 years (IAEA, 2009), suggesting that time frames for safety could also be much less than 300 years. The half-lives of uranium (as U^{238}) and

[3] EW – exempt waste.

thorium, however, are 4.5 and 14.1 billion years, respectively (see Langmuir, 1997) – meaning that an institutional control period of no more than 300 years is patently inadequate for isolating such long-lived radionuclides in a shallow tropical context. The waste therefore represents an indefinite or perpetual management risk to the surficial environment and nearby communities.

A relevant example is the Ranger uranium mine in Australia. The mine recently closed and is now completing extensive rehabilitation works. The tailings from the processing of the uranium ore are considered to be long-lived low level radioactive waste – with an average uranium concentration of ~230 mg/kg (~5.8 Bq/g) (data updated from Mudd, 2014) (thorium levels are considered negligible). This is a level of radioactivity slightly lower than the WLP residue (i.e. 5.8 vs 7 Bq/g). Two key criteria for rehabilitation are that[4]:

11.3i the tailings are physically isolated from the environment for at least 10,000 years;

11.3ii any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.

This demonstrates the seriousness of addressing the WLP as long-lived low level radioactive waste and finding engineering solutions which address the effectively permanent nature of the radioactivity (at least in human time scales).

Water Quality

There has been some testing of potential WLP leachate, based on standard leachate toxicity characterisation tests (the TCLP and TTLC tests), results given in Tables 5.3.2 and 5.3.3 in Chapter 5 of the EIA. Whilst most results are below the stated regulatory criteria for the TCLP or TTLC tests, there some results which exceed the criteria very substantially. For example, heavy metals below the TCLP and/or TTLC criteria include antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, thallium, vanadium and zinc (though only marginally for lead). This suggests that WLP leachate may have low heavy metal concentrations – although there are significant potential oversights (see below) and little discussion or explicit justification of these tests and their applicability to a PDF of WLP residue in the Kuantan context. That is, the TCLP was developed to test for the potential leachate characteristics of municipal landfills – certainly not thorium-dominant radioactive wastes such as WLP residue in the climate context in Kuantan.

In sub-section 5.5.2, an assumption is made that any leachate from the PDF would lead to a mixture of 95% surface runoff with 5% raw leachate (results given in Table 5.5.6) – although the actual (or raw) leachate chemistry itself is not provided. The diluted discharge would include several metals at concentrations of environmental or public health concern (based on the authors' experience and knowledge of water quality guidelines in Australia and around the world), such as: cadmium (0.02 mg/L), iron (200 mg/L), manganese (65 mg/L), nickel (2.00 mg/L), zinc 55 (mg/L).

More specifically, sulfur is presented as 'sulphide' – with a value of 2,000 mg/L. This must be an error, as this concentration of sulfur in the form of sulphide would be extremely toxic and highly

[4] See: www.environment.gov.au/science/supervising-scientist/publications/environmental-requirements-ranger-uranium-mine

reactive and chemically impossible to find in the WLP residue in the first place. We therefore assume that it is in the form of sulphate (i.e. SO_4). Given a diluted value of 2,000 mg/L, this suggests that raw leachate could have a sulphate concentration of 40,000 mg/L (i.e. going from 5% to 100% and assuming no sulphate in surface runoff), a value of great significance, if the extent of dilution of WLP leachate with surface runoff is weaker than 20-fold. Even still, a sulphate value of 2,000 mg/L would represent a major ecotoxicity threat to freshwater biodiversity (based on the authors' experience).

It should also be noted that the detection limits of '<1 mg/L' for metals such as copper or lead are far higher than environmentally relevant concentrations, meaning these metals could be causing harm due to the lack of chemical analyses which use sufficiently low units. Detection limits should have been in micro-grams per litre (e.g. <0.1 µg/L) to allow quantification at potentially environmentally significant concentrations below the detection threshold.

Finally, Table 5.5.6 includes guideline criteria for industrial effluent or landfill-related sites – both of which have no material relevance to the WLP residue and rare earths processing. We believe the correct guidelines or criteria which the leachate should be compared with are those for freshwater ecosystems and not industrial-related treatment guidelines. In this way, the true performance of the leachate treatment plant and its suitability for protecting ecological as well as human health in the context can be assessed.

Conceptual Engineering Design of the PDF

We believe that the engineering design of the PDF fails to take into account numerous aspects and is at serious risk of failing to contain the WLP and prevent, or at least minimise, potentially hazardous solutes escaping from the PDF into the surrounding environment. Specifically, these issues include:

- *Reliance on geosynthetics:* the design relies on the use of geosynthetic clay liners and plastic sheets (as HDPE) as the primary containment barrier for the WLP residue. The expected useful life of such covers cannot be expected to last more than 100 hundred years (based on typical engineering design life considerations for these products). This needs to be compared to the nature of the WLP residue and the long-lived radionuclides it contains, especially the thorium – highlighting that future failure of these covers would materially compromise the integrity of the PDF and expose future generations to risk or at least burden them with costly interventions and remediation.

- *Cover Design:* we believe the relatively thin nature of the proposed cover, including geosynthetics and HDPE plastic covers, 0.15 m sand and 0.3 m cobbles for drainage with 0.9 m of compacted earth fill on top, is insufficient for the nature of the WLP residue and tropical climate. There appear to be no engineering studies completed which model the performance of this cover design – leading to assessments of infiltration rates into the underlying WLP residues and therefore potential leachate generation rates. This requires the use of unsaturated flow models, a practice widespread for cover designs in the landfill sector or for soil covers to reduce acid mine drainage from mine wastes (especially sulphidic waste rock dumps). The nature of the PDF design relies on drainage to work continually to maintain the capillary break behaviour. However, the thin nature of the overall cover design raises serious questions about long-term performance and reliability. For example, similar thickness covers were used for the rehabilitation of sulphidic waste rock dumps at the former Rum Jungle uranium mine in northern Australia – yet these covers were failing within a decade, due to the wet-dry monsoonal climate (relevant in the proposed site), despite an expected engineering design life of 100 years (Mudd & Patterson, 2010). Furthermore, if there are periods of intense and above average rainfall, the cover could easily become fully saturated and fail to perform as a shedding structure and instead facilitate significant rates of infiltration – leading to excessive leachate generation and associated risks.

- *Climate Change:* there appears to be no assessment of the risks of climate change for the PDF, let alone any modelling of the risks of varying rainfall on cover performance. This is a critical failure given the risks which climate change – in particular the increased frequency and severity of large rainfall events – can present to the hydrological performance of such waste disposal facilities.
- *Vegetation and Tree Roots:* there appears to be no recognition of the risks that trees growing the PDF can lead to their roots penetrating the cover. This leads to holes in the cover and significant risks of increased infiltration and leachate generation.

Overall, we believe that the justification and assessment of the PDF design remains poor with respect to common and critical engineering risks such as cover design and materials, water balance and flows, climate change and vegetation.

Groundwater and Surface Water Risks

The risk of siting the PDF within a catchment that supplies water to the City of Kuantan, and which is located in a monsoonal climate (with not inconsiderable flood risk), appears to have been given inadequate consideration, particularly on the long timescales required to characterise solute and radionuclide migration from such a facility.

We note that stretches of the Sg. Ara river, into which treated effluent will be discharged, are ephemeral, meaning periods of no flow. Along such stretches of river, the dilution capacity for the leachate will be effectively zero, resulting in concentrations the same as the discharge. A full and thorough ecological and human health risk assessment which incorporates the seasonal dynamics and gaining/losing behaviour of the rivers within the catchment is required to fully understand such risks and determine potential impacts in downstream locations.

Based on the Executive Summary, groundwater risks appear to be poorly assessed. Although solute transport modelling was completed, there appears to be little to no recognition of the role of groundwater-surface water interactions, especially important during periods of low rainfall. If there are periods of low rainfall and flows in streams, this could mean that any leachate or impacted waters from the PDF enter a stream with minimal to no dilution, exacerbating impacts and risks to aquatic biodiversity, ecosystem values, and (potentially) human health through ingestion of drinking water. This is an area which requires considerable attention given the climatic and geographical context of the proposed PDF site.

The assumption that placing the WLP residue 5 m above the water table, with local sandy silt material emplaced in between, will effectively prevent leaching of hazardous leachate to groundwater is highly questionable. The thickness (30 cm) and permeability of this material (assumed to be $<10^{-7}$ m/sec, but unverified with detailed field and/or laboratory testing) is by no means enough to prevent leaching in the long term, and there would remain significant potential for mobilisation of leachate to groundwater during heavy rain events. Risk assessment and solute transport modelling must account for the monsoon climate and long-timescales required to prevent leaching to groundwater, informing a more robust assessment of this risk.

In addition, whilst heavy metals can be expected to have substantial retardation (K_d) factors, it is unrealistic to assign high K_d values for sulphate. This means that it is hard to accept that sulphate will have low migration potential (as implied on page 17). Finally, it should be noted that the scenario which models migration to reach downgradient monitoring bores within 50 years should be compared to the perpetual nature of the WLP residue – meaning that assessment of solute migration should, at the very least, follow the example set by the Ranger uranium mine and assess time frames of 10,000 years (see earlier commentary).

We re-iterate that in the current form outlined in the EIA, this proposal involves multiple risks of significant magnitude which require further thorough and comprehensive assessment, made subject to independent scientific, engineering and public review.

Yours Sincerely,

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