

Rare Earth and Radioactive Waste

A Preliminary Waste Stream Assessment of the Lynas Advanced Materials Plant, Gebeng, Malaysia



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National Toxics Network

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Executive Summary

Lynas Corporation, an Australian based mining company are constructing a rare earth processing plant, known as the Lynas Advanced Materials Plant (LAMP) in Gebeng industrial estate in Kuantan, Malaysia. The LAMP will process lanthanide concentrate which will be trucked from the mine site in Mt Weld Western Australia to the Port of Fremantle where it will be shipped to Malaysia. This report provides an assessment of the emissions from the LAMP plant rather than Lynas Corporation's activities in Western Australia. The LAMP plant will have significant atmospheric, terrestrial and waterborne emissions of toxic chemicals and radionuclides including uranium, thorium and radon gas.

The LAMP is poorly situated for a refinery with large scale emissions – particularly radioactive tailings. The high rainfall, low evaporation and unstable geotechnical environment create elevated risks for the radioactive tailings waste and dramatically increase the risk of environmental contamination. Serious questions have also been raised by Lynas' consulting engineers and materials suppliers about poor construction methods for the LAMP which will leave it open to critical process failure risks and environmental contamination.

The most significant source of pollution from the LAMP will be the solid waste or tailings. Due to local environmental conditions and technical limitations of containment cells it is highly likely that the radioactive waste will contaminate groundwater within months of deposition on the site. Lynas and the Malaysian Atomic Energy Licensing Board have failed to meet the International Atomic Energy Agency's requirements regarding long term plans for the radioactive solid waste.

The LAMP radioactive waste will require isolation from the environment for hundreds of years. Current disposal plans are likely to lead to groundwater contamination within months. Alternative plans to convert the waste into product are also flawed based on similar approaches, using similar waste in other jurisdictions. Radiation and contaminant levels proved to be a barrier to commercialisation. Airborne particulate contamination from the residue ponds also appears inevitable.

Contamination of the Balok River and receiving marine environment are highly likely based on the poor waste water discharge limits set by Malaysian authorities. These limits do not equate with international best practice for waste water discharge. Radionuclide contamination of waterways and aquatic biota has been poorly addressed in Lynas' Environmental Impact Assessment (EIA) documentation.

Atmospheric contamination by acid gases will eventuate if the flue gas pollution scrubbers are not maintained in pristine condition or are incapacitated by power outages. It is to be expected that emissions of SO_x, HF and NO_x will exceed international guidelines if the scrubbers deteriorate in efficiency over time. Fugitive emissions from waste and concentrate

stockpiles also present a significant hazard. Approval for the LAMP should not have been issued on the basis of the EIA provided by Lynas due to inadequate analysis of environmental impacts and predictive modelling and their failure to meet IAEA requirements for permanent disposal.

Key Recommendations

Recommendation 1.

The matter of long-term disposal of the radioactive waste from the LAMP must be resolved immediately. When the entire decay chain radioactivity of the waste is accounted for specific radiation levels are as high as 61 Bq/g. This clearly places the waste in the Low Level Waste (LLW) category for radioactive waste requiring isolation for hundreds of years. Even if only the radioactivity of the parent radionuclides, thorium and uranium, are considered then the level of 6.2 Bq/g places the waste firmly in the LLW category according to best practice regulations. The environmental and human health risk assessment of this radiation exposure is clearly inadequate and the disposal methods very poor in an inappropriate environment. Under these circumstances it would appear that environmental radioactive contamination and human exposure is unavoidable. This proposal would not be approved in Australia and the Malaysian government should revoke the temporary operating licence on this basis.

Recommendation 2.

It is clear that no licence should be issued for the LAMP to operate until all of the issues related to the long term management of LAMP waste and construction inadequacies have been resolved. The issue of the pre-operating licence by the AELB on February 2, 2012 ignores this fundamental requirement and places the environment and public health at serious risk. A proposal would not be approved in Australia without this information.

Recommendation 3.

The LAMP plant should not be permitted to operate until the ecological and public health impacts of effluent release to the Balok River have been modelled and assessed in detail. The modelling should include ecotoxicology assessment on endemic biota, food web assessment and a quantitative analysis of human health impacts from river users and consumers of aquatic biota. The lack of data on these issues renders the Lynas EIA well below international standards and insufficient for granting of operational licences.

Introduction

The Lynas Advanced Materials Plant (LAMP) is currently under construction in the Gebeng industrial estate in the locality of Kuantan, Malaysia. The purpose of the plant is to refine lanthanum oxide and other rare earth concentrates for use in final products. The proponent of the project is Sydney based Lynas Corporation which operates a rare earth mine in Mt Weld, Western Australia. The Mt Weld mine is the source of the lanthanum concentrate that will be processed in Malaysia. While this report primarily addresses the emissions and waste from the LAMP plant in Malaysia some reference will be made to the Western Australian operation where data is considered relevant.

Rare earth refineries have a reputation for being highly polluting based on information arising from Chinese operations (China produces most of the rare earth products globally) and from previous Malaysian operations¹. Air emissions, contaminated process water and residual solid wastes from acid extraction and solvent leach beneficiation of rare earth concentrates have grossly polluted large areas in China, particularly around Baotao. Chinese experts² have also pleaded with government to act on contamination of the Yellow River by radioactive thorium – a byproduct of rare earth processing that has migrated into the river system.

This report considers the liquid, solid and gaseous emissions of the LAMP and examines the implications for the environment and public health in the Kuantan region. Information is drawn from Lynas Corporation documents, regulatory documents from Australia and Malaysia and international literature review.

Key factors to consider include more than just predicted emissions under normal operating procedures but also the potential for emissions during power outages, accidents and spills and their long-term implications. The effectiveness of national regulatory controls in the short and long term (>100 years for radioactive wastes), enforcement and licence conditions must also be taken into account. The public must question whether Lynas will accurately report any emissions in a timely way to regulators and the public as they have withheld critical regulatory documentation from the public in WA. It remains to be seen whether emission data will be accurately reported to regulators or whether enforcement of regulations will be adequate to protect the environment and public health. These factors can dramatically increase the risk of adverse impacts from emissions.

¹ Bradsher, K., (2011) *Mitsubishi Quietly Cleans Up Its Former Refinery*. The New York Times. March 9, 2011, on page B4

² Xu Guangxian et al, "An Emergency Call for the Protection of Thorium and Rare Earth Resources at Baiyun Erbo and the Prevention of Radioactive Contamination of the Yellow River and Baotou," Chinese Academy of Sciences news site, October 20, 2005, <www.cas.ac.cn/html/Dir/22005/11/17/5793.htm>.

The National Toxics Network (NTN) is of the view that the citizens of Kuantan have a right under International Agreements to have access to information on the chemicals they will be exposed to and the risks that Lynas intend to expose them to in order to make profits for its shareholders. NTN has produced this report to address the lack of information provided by Lynas to the public about the emissions it will create in Kuantan and their potential impacts on human health and the environment.

Pollution from rare earth processing

Historically China has been the main global producer of rare earths accounting for up to 90% of global production³. In previous decades the Chinese have emphasised production over environmental regulation allowing pollution to occur as a result of rare earth mining and refining. The result has been severe localised environmental contamination in areas where these activities take place. In turn, residents of these areas have reported high rates of respiratory illness, skin diseases, cancer and birth deformities.

The rare earth industry in China provides a grim example of the worst case scenarios that could be expected in terms of environmental and human health impacts from rare earth processing. The proponents of the LAMP claim to address these pollution issues in such a way as to have no impact on the environment or human health. On the available evidence this argument cannot be sustained and significant impacts are likely to occur.

Due to difficulties in obtaining official data on public health impacts of rare earth processing in China researchers have to rely on anecdotal evidence and extrapolation from environmental contamination data. However the weight of evidence regarding environmental contamination supports the concern that significant public exposures to toxic by-products of the industry and health impacts would be expected.

At least one Chinese study comparing children exposed to rare earth elements (REE) to a control group of non-exposed children concluded that *'children aged 7-10 years in RE ore area may have higher REEs burden in the body, and exposure to REEs could have adverse influences in children'*⁴. The study found that increased exposure to rare earth elements correlated with statistically significant lymph system changes and lower IQ levels.

This study refers specifically to rare earth element exposure which can result from environmental mobilisation of these elements through emissions to atmosphere, water and land. In the context of the Malaysian LAMP plant the sources of rare earth element exposure would be from air emissions, fugitive dust and contaminated water discharges.

³ Humphries, M., (2011) Rare Earth Elements: The Global Supply Chain. Congressional Research Service. R41347. September 2011.

⁴ Fan G, Yuan Z, Zheng H, Liu Z. (2004) Study on the effects of exposure to rare earth elements and health-responses in children aged 7-10 years *Wei Sheng Yan Jiu*. 2004 Jan; 33(1):23-8. School of Public Health, Jiangxi Medical College, Nanchang 330006, China.

Over the projected 10-12 years of operation of the LAMP the cumulative levels of rare earth elements can be expected to rise in the environment surrounding the plant as the REE migrate through fugitive stockpile emissions and stack emissions. These transport methods will deposit REE on soil and into the sediments of surface water bodies. REE will also migrate through wastewater discharges and leakage from tailings ponds. The Balok River sediment can be expected to act as a reservoir for REE due to deposition from treated waste water discharges.

The rapid growth of the rare earth industry in China has outstripped the ability of regulators to restrict discharges and as a result there has been no effective way to control the usual pollutants such as ammonia, nitrogen, and thorium dust, which are emitted during the production phase⁵.

Cindy Hurst, a researcher with the Institute for the Analysis of Global Security has analysed some impacts of the Chinese rare earth industry and cites an article published by the Chinese Society of Rare Earths⁶,

“Every ton of rare earth produced, generates approximately 8.5 kilograms (18.7 lbs) of fluorine and 13 kilograms (28.7 lbs) of flue dust; and using concentrated sulfuric acid, high temperature calcination techniques to produce approximately one ton of calcined rare earth ore generates 9,600 to 12,000 cubic meters (339,021 to 423,776 cubic feet) of waste gas containing dust concentrate, hydrofluoric acid, sulfur dioxide, and sulfuric acid, approximately 75 cubic meters (2,649 cubic feet) of acidic wastewater, and about one ton of radioactive waste residue (containing water).”

By extrapolation using Chinese industry data the LAMP, which is expected to produce 22,500 tonnes per annum of lanthanum oxide equivalent will generate *annual* waste streams of:

- 191.25 tonnes of fluoride compounds
- 292.50 tonnes of flue dust particulate
- between 216 million m³ and 270 million m³ of waste gas (containing NO_x, CO, SO₂, HF, dust concentrate and H₂SO₄)
- 1,687,500 m³ of acidic wastewater and
- 22,500 tonnes of radioactive waste residue (containing water).

The critical issues surrounding the LAMP plant centre on the control and disposal of these large amounts of waste during its operation and for decades into the future. In terms of the radioactive components of the waste stream control methods are likely to be required for hundreds of years.^{7 8}

⁵ Hurst, C., (2010) China's Rare Earth Elements Industry: What Can the West Learn? Institute for the Analysis of Global Security (IAGS), U.S. Army's Foreign Military Studies Office, Fort Leavenworth. Kansas. p.18

⁶ <http://www.cs-re.org.cn/english/>

⁷ Department for Environment, Food and Rural Affairs, "Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom" London, 2007

⁸ International Atomic Energy Agency. (2009) IAEA SAFETY STANDARDS SERIES No. GSG-1 Radioactive Waste Classification.

The radioactive elements ThO₂ (Thorium Dioxide) and U₃O₈ (Uranium Oxide) are present in the rare earth concentrate (the feedstock for the LAMP) at a concentration *significantly* elevated above naturally occurring radioactive material (NORM) levels that are found in the rare earth ore at Mt Weld⁹, Western Australia. The rare earth ore has been artificially concentrated at Mt Weld thereby raising the radioactivity levels. According to USEPA classification criteria the concentrate should be defined as Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) and should be regulated accordingly. US regulators are currently debating tighter controls on TENORM because of its *potential to expose the public to elevated radiation levels*. Contrary to claims by Lynas the radiation levels are not *'natural'*.

Thorium levels of approximately 1700ppm and uranium levels of around 30ppm in the concentrate will result in a specific radioactivity level between 3.5 and 8 Bq/g. The processing, chemical treatment and beneficiation of the rare earth ore at the concentrator plant at Mt Weld mean that the material is no longer 'naturally occurring' but should be classified as Technologically Enhanced Naturally Occurring Radioactive Material (TENORM).

As the uranium and thorium are not the target of rare earth refining they will be screened into the waste stream and form a fraction of the 'paste' material that will be generated as waste tailings from the LAMP process that will be disposed of in ponds on-site. It has been foreshadowed by Lynas that this waste will be 'recycled' into building materials but previous international experience has shown that this is a dangerous and impractical proposal due to contamination and radioactivity.¹⁰

It is expected that Lynas will claim that the LAMP is more sophisticated and has more environmental controls than the rare earth refineries in China and that may be correct. However, the basic processes for extraction of rare earth from concentrate are similar wherever the activity is conducted. In terms of environmental impacts a more 'sophisticated' plant really means a higher level of pollution controls. This raises other issues.

Chinese rare earth production has been highly polluting because the waste products have been released into the environment indiscriminately and because emissions have not been controlled by filter mechanisms such as flue gas scrubbing.

However, compared to unrestricted emissions, the addition of scrubbers or baghouse filters to smokestacks, treatment of wastewater and higher efficiency processing methods leads to a much higher capture rate for contaminants leading to a higher concentration of hazardous materials in the wastes. The emissions are not destroyed by pollution control devices; they are just more effectively captured in the waste streams.

⁹ Tsurikov, N., (2008) Measurements of Radioactivity Levels from a Sea Container with Lanthanide Ore at the Mt Weld Site, Lynas Corporation. Radiation Management Plan.

¹⁰ Southwell, M., (2002) *Residue used in Bricks: Tests show house radioactive*. The West Australian Newspaper. February 1, 2002. p.3

The two critical questions that arise as a result of concentrated wastes in pollution scrubbing are a) how efficient are the pollution control filters?
b) how will the captured hazardous waste be stored or disposed of?

In the case of the LAMP there are significant problems and inadequacies in how these wastes are proposed to be managed which are discussed below.

In addition to hazardous waste products, many of the processing agents and chemicals used to refine rare earths are intrinsically hazardous or have the capacity to exacerbate environmental impacts when they merge with waste streams.

Common technologies for refining rare earth elements require chemicals such as ammonium bicarbonate and oxalic acid. Oxalic acid is poisonous and potentially fatal if swallowed. It is also corrosive and causes severe irritation and burns to the skin, eyes, and respiratory tract, is harmful if inhaled or absorbed through the skin, and can cause kidney damage¹¹.

Lynas also intend to use large amounts of sulphuric acid, hydrochloric acid, magnesium oxide, kerosene and proprietary solvents including trichloroethylene (TCE) in the refining process. Storage of these chemicals must include sufficient bunding (raised concrete 'dams' that chemical tanks must be located within) to ensure that any spills are captured, do not react with other chemicals and are not directly released to the environment.

It is of considerable concern that the LAMP proposes to discharge wastewater to the Balok River. Critical contaminants associated with the waste stream from the plant (such as solvents) are not regulated under Standard B discharge limits of the *Environmental Quality Act 1979* of Malaysia which is the proposed criterion by which to assess wastewater from the LAMP plant before it is discharged to the Balok River.

LAMP Process Description

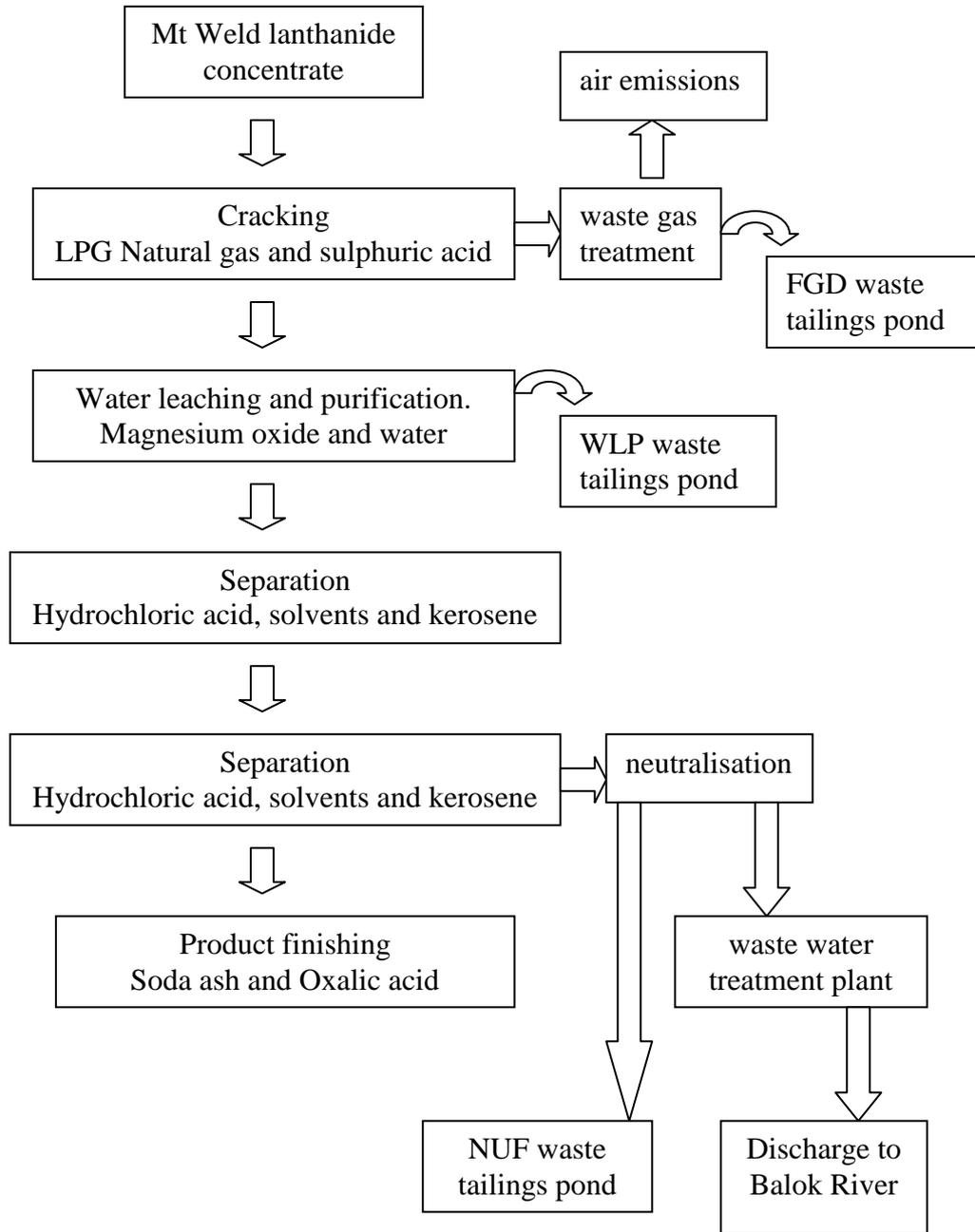
The extraction of rare earth product from the Mt Weld concentrate involves a series of thermal, chemical and physical processes. Each process generates different forms of waste material. The main processing activities associated with the rare earth extraction are;

- Cracking (ore calcining)
- Waste Gas treatment
- Leaching (primary secondary and tertiary)
- Upstream extraction
- Downstream extraction
- Product finishing¹²

¹¹ op cit. 5 at 18.

¹² Worley Parsons (2008) Lynas Advanced Materials Project. Conceptual Design for Residue Storage Facility – Gebeng. p.1

Process Schematic for the LAMP plant



Tailings disposal ponds

Of the emissions to air, water and land the most hazardous aspect of the LAMP plant is likely to be the solid waste disposal to land followed by the waste water discharge to the Balok River.

Acid gas emissions to air will be controlled to some extent but only if LAMP uses the US pollution control scrubbers they have specified. These will decrease in efficiency unless maintained in pristine condition, allowing air pollution to rise over time. Most of the land based waste material will consist of process wastes containing metals, residual solvents and radionuclides left after the rare earth product is separated from the ore concentrate.

According to Lynas consulting engineers Worley Parsons¹³ the LAMP plant will generate increasing rates of 'solid' waste in the form of tailings as the production output ramps up after the commissioning phase.

The tailings waste will be disposed of in at least three separate waste ponds which are referred to as residue storage facilities. The term 'storage' is used rather than 'disposal' as there is an assumption by Lynas that the waste materials will be utilised in other industries such as construction. Lynas only have enough on-site 'storage' for six years of waste and are relying on being able to market its waste as 'product' to make up the shortfall of disposal space. The reality is that these materials are unlikely to ever leave the site and will remain in the tailings ponds long after the operational life of the LAMP.

The three main streams of solid waste are;

- Flue gas desulphurisation residue (FGD)
- Water Leach Purification residue (WLP)
- Neutralised Underflow Residue (NUF)

Table1. LAMP Solid Waste generation

Waste type	Tonnes per annum (1st year)	Tonnes Per annum after 2nd year onwards¹⁴	Volume in ten years (m³)
FGD	27,900	55 800	162 600
NUF	85,300	170 600	91 600
WLP	32,000	64 000	478 800
Total	145 200	290 400	1 392 700

¹³ op cit. 12 at 5.

¹⁴ production and waste will double after 12 months when Phase Two of the LAMP begins.

Of all the waste streams, the WLP is considered to be most toxic due to its elevated levels of uranium, thorium and associated radioactivity as well as heavy metals when compared to NUF and FGD waste. The tailings ponds will have surface water detention ponds to capture 'surface water' (largely from rainfall) and 'supernatant liquors' which are process fluids that separate from the solid waste 'paste' after it has been dumped. According to the Lynas EIA documents the water and other liquids from these ponds are intended to be *discharged into the environment*. Lynas engineering consultants have documented that some of the constructed embankments to contain the waste will actually be made out of the waste itself instead of clean soil or other imported materials.

However, Lynas admit that (in at least the case of the WLP waste) the toxicity of the waste will preclude this construction method. Any surface water or supernatant liquors from the WLP pond will be sent to an isolated pond and cannot be discharged to the environment though they may be reused in the production process. Similarly, the WLP waste cannot be used in embankment construction due to the danger of it entering the environment.

The waste water treatment plant will also generate up to 2000 tpa of biosludge which will also be disposed of to the WLP tailings pond¹⁵. The biosludge is likely to contain residual uranium, thorium and other hazardous materials as a result of the concentration of contaminants in the water filtration process.

Radioactivity of tailings

The tailings waste streams will contain a range of metallic elements that have been separated through the refining process as well as remnants of process chemicals. The Lynas EIA documentation and associated consultants reports indicate that the Water Leach Purification (WLP) process will generate the most radioactive and contaminated tailings.

The WLP waste will contain the majority of uranium and thorium that is separated from the final rare earth products during the refining process. The concentrate that is used as feedstock for the refining process contains uranium (30ppm) and thorium (approx 1700ppm) that generates between 3.5 and 8 Bq/g of specific activity. This represents only the parent radionuclide activity and not the entire decay chain. As virtually all of the radioactive elements are removed during the refining process it is expected they will be transferred to the waste streams and disposed of in the tailings ponds. The WLP will contain the majority (though not all) of the uranium and thorium.

The WLP waste is reported by Lynas Corporation to have a specific radioactive concentration of 6.2 Bq/g. This is within the average range of activity quoted by Lynas for its Mt Weld concentrate.

¹⁵ Nuklear Malaysia (2010) Radiological Impact Assessment of Advanced Materials Plant Gebeng Industrial Estate Kuantan, Pahang. June 2010 p27

At this concentration the WLP radiation levels are two magnitudes of order higher than existing background radiation levels attributable to thorium-232 and uranium-238 in the natural environment around Pahang which is within the range of 0.08 +- 0.05 Bq/g and 0.07 +- 0.04 Bq/g respectively¹⁶. These background levels were assessed by the Malaysian Nuclear Agency.

However, Lynas consultants Nuklear Malaysia quote the radioactivity concentrations in both the Mt Weld concentrate and the WLP residue as 61 Bq/g¹⁷.

This concentration refers to the radioactivity of the entire decay chain of the thorium and uranium and includes decay products such as radium and radon. Each of these decay products must also be assessed for environmental and human health risk assessment in the context that it is highly likely that these materials will leave the boundary of the property due to inadequate disposal and storage practices, leakage, fugitive emissions and associated contamination. This assessment, including modelling of impacts, has not been completed by Lynas or its consultants.

In addition to the WLP waste the LAMP it is claimed the LAMP will generate;

- flue gas desulphurisation residue (FGD) with a radioactivity concentration of 0.47 Bq/g (12ppm thorium-232 and 0.3 ppm uranium-238)
- neutralisation underflow residue (NUF) with a radioactivity concentration of 0.25 Bq/g

Other assumptions in Nuklear Malaysia's modelling of radioactive exposure of the public and workers from tailings and emissions also need to be questioned. The contribution of FGD and NUF waste to public and worker radiation exposure are disregarded entirely on the basis that the levels in the waste are the same as natural background levels in soil at Pahang. However, the figures quoted in Nuklear Malaysia's report demonstrate that the FGD/NUF waste is two magnitudes of order higher than background levels. The contribution of the radioactivity from FGD and NUF has been omitted from the modelling and it is unclear why such an obvious error has been permitted.

In addition, Nuklear Malaysia assume dust particles from the concentrate and tailings will be of the size PM 5 (particulate matter of a size 5 microns and greater) for all dust assessment. However, similar processes for the extraction of alumina hydroxide in Western Australia result in tailings that have a high proportion (up to 50%) of fine particles in the vicinity of PM <2.5.

In health terms the difference is highly significant as even non-radioactive PM 2.5 can penetrate deeply into the lungs causing serious respiratory diseases whereas PM5 -10 is mostly trapped and removed by the human

¹⁶ ibid p30

¹⁷ ibid p37 and p 38

respiratory system. If the PM 2.5 contains alpha emitting radioactive particles they can become embedded in the lining of the lungs and cause serious disease including cancer.

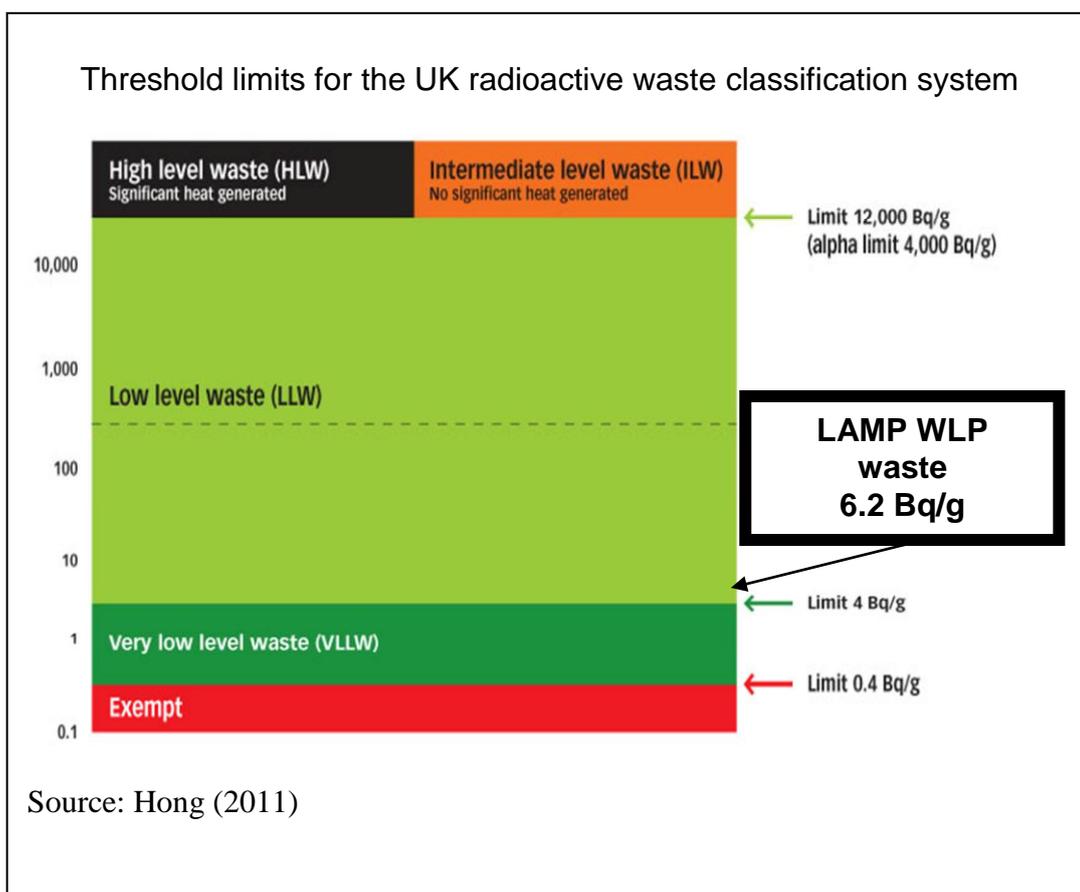
Nuklear Malaysia use the rationale that monitoring at 'dusty plant operation'¹⁸ averaged particulate from PM2 – PM10. From these figures Nuklear Malaysia assumed a median particulate size of PM 5 for use in radioactive exposure modelling. There is no reference to which industry or material was monitored. The average size of particles is largely irrelevant for risk assessment purposes. The actual count of ultrafine particles is extremely important as these are critical for respiratory impacts and the reduction in particle size by one half can create up to eight times the surface area for contaminants to adhere to. Once again this represents a serious miscalculation in the radiological dose and exposure modelling by Nuklear Malaysia that must be resolved before any operating licence can be issued for the LAMP.

The level of risk that should be assigned to the radioactive waste from the LAMP plant and the form of storage and disposal it requires is not made clear in any of the EIA documents submitted to the Malaysian government by Lynas. The International Atomic Energy Agency (IAEA) and national governments in some developed countries provides guidance documents to assist proponents and regulators to manage this form of waste.

The UK and a number of other European countries¹⁹ use similar concentration ranges of radioactivity to classify hazardous waste. In Malaysia the discretion to classify and manage the radioactive waste from the LAMP plant is the responsibility of the Atomic Energy Licensing Board (AELB) of Malaysia.

¹⁸ *ibid* p57

¹⁹ P. Vankerckhoven (Ed.), (1998) "Radioactive waste categories - current position (1998) in the EU Member States and in the Baltic and Central European countries, EUR 18324 EN.



Unless the AELB intends to deliver an outcome that is substantially below world’s best practice for the storage of low level radioactive waste it should implement the UK classification system or a system that exceeds the protection levels of the UK system²⁰. The threshold levels for the hierarchical categories that are implemented in the UK are depicted above²¹.

The International Atomic Energy Agency (IAEA) review of the LAMP plant was very critical of the waste disposal plans proposed by Lynas. In particular they focused on the complete lack of long term disposal options in Lynas Corporation’s documentation.

The IAEA could have been more specific in their criticisms by reference to their own General Safety Guide (GSG) series and in particular the IAEA Radioactive Waste Classification. IAEA No.GSG-1²². This guide describes the necessary long term disposal requirements for low level radioactive waste (LLW) such as the WLP waste from the LAMP plant. According to the IAEA GSG LLW requires isolation and containment in engineered near surface facilities for *several hundred years*. Near surface containment disposal can

²⁰ op cit. 7

²¹ Graphic sourced from Hong, C.H., (2011) *Comments on the IAEA Peer Review Report on the Radiation Safety Aspects of a Proposed Rare Earths processing Facility (The Lynas Project)*.

²² IAEA, “Radioactive Waste Classification”. IAEA No. GSG-1 , Vienna, 2009

occur to various depths up to 30 meters and applies to waste that has long lived radionuclides at lower levels of activity concentration such as LAMP WLP waste. Such waste would require containment over long periods for which institutional controls and regulation can be guaranteed to prevent environmental contamination and human health impacts.

The flawed and limited on-site disposal plan proposed by Lynas is a clear sign that Lynas are relying on 'product commercialisation' to reduce aggregate waste volumes over time. Lynas LAMP documentation allows only for short-term containment using technology that is highly likely to be breached by contaminants within months of commissioning based on the failures of similar technology in other jurisdictions including the Mt Weld site in WA.

The proposed short term containment has poor structural integrity which will be exacerbated by environmental conditions (seismic activity, flooding, unstable geotechnical conditions and monsoonal activity). The small size of the containment structures proposed is clearly inadequate to deal with more than the first six years of production or the monsoonal rains given relatively low evaporation rates.

The limited and flawed on-site disposal options appear to drive Lynas' reliance on a strategy to 'sell' their waste as input materials for construction and agricultural use. The contamination of the Lynas waste with radionuclides, heavy metals and other chemicals has proven a major barrier to uptake of this type of waste material in the building and agricultural sectors in developed countries and should not be considered in Malaysia.

The problems Lynas face with long term waste disposal at Kuantan have resulted in a statement by the Malaysian atomic regulators (the AELB) that Lynas must provide an acceptable proposal for disposal in Malaysia within 10 months or consider re-export of the radioactive waste to Western Australia for interment at the Mt Weld site or another Western Australian location²³.

The Malaysian government have recently issued a pre-operating license permitting Lynas to operate the LAMP plant for two years before they can be considered for a permanent operating license. In effect the Malaysian government and the AELB have ignored the recommendations of the International Atomic Energy Agency who recommended in their review that;

The AELB should require Lynas to submit, before the start of operations, a plan setting out its intended approach to the long term waste management, in particular management of the water leach purification (WLP) solids after closure of the plant, together with a safety case in support of such a plan²⁴.

²³ <http://www.abc.net.au/news/2012-02-02/malaysia-approves-australian-rare-earths-plant/3806100>

²⁴ International Atomic Energy Agency (2011) *International Review mission on the Radiation Safety Aspects of a Proposed Rare Earths Processing Facility (the Lynas Project)* 29 May – 3 June 2011, Malaysia. Recommendation 1.

Airborne pollution from tailings ponds

The tailings which will be generated by the LAMP plant originate from soil structures that are common in Western Australia. While the ore that is used as feedstock for the LAMP plant has a higher than usual concentration of lanthanum oxides, it has a similar distribution of other elements that are common in Western Australian soils and ores.

The alumina refining industry in Western Australia has generated millions of tonnes of tailings that have a similar profile to the tailings that will be generated by the LAMP plant including elevated levels of thorium and uranium.

They also have a high content of very fine particulate that results in high potential for dust lift off under windy conditions when it has dried out following disposal. This material is known as 'red mud'. The high potential for this material to become airborne and the small particle size significantly increase the health risks associated with exposure to the waste. Of even greater concern is the potential for alpha emitting particles to adhere to other waste particles and subsequently be inhaled by workers or the public when blown off-site.

According to the Argonne National Laboratory,²⁵
Ores and tailings containing uranium-238 and thorium-232 are very mobile as dust resulting in air and soil contamination, where radon-222 gas is constantly released. The decay products of radon-222 gas in air represent the greatest risk to developing cancer. The energetic particles can be inhaled and harm lung tissue to the extent cancerous cells can develop. These carcinogenic effects can be observed in all living organisms.

The red mud has a uranium concentration of 15–23ppm and a thorium concentration of 250-271ppm²⁶. This is significantly less than the 30ppm uranium and 1700ppm thorium contained in the WLP waste from the LAMP.

The red mud tailings in WA are stored in large tailings dams. In Western Australia they are called the 'red mud ponds'. These waste ponds have been controversial due to a range of contamination issues that have arisen over the three decades they have operated.

A major concern for environmental regulators in Western Australia has been the repeated occurrences where large 'dust clouds' of the red mud have been blown from the disposal ponds and swept across the landscape inundating homes and farms with the fine red tailings. Many residents in the areas around the red mud ponds have claimed to have experienced health problems

²⁵ Argonne National Laboratory (2005) cited in Campbell, G., and Paul, J., (2011) *Investigating Rare Earth Element Mine Development in EPA Region 8 and Potential Environmental Impacts USEPA EPA Document-908R11003 p15*

²⁶ URS and CSRP (2010) *Bauxite Residue (Alkaloam®) Sustainability Assessment: Technical, Community Consultation, Benefit-Cost and Risk Assessment p57*

as a result of their exposure. A prominent alumina refining company was found guilty of breaching its operating licence in 2006 for failing to prevent the contaminated dust from leaving the waste ponds and was also found guilty of similar pollution charges in December 2004²⁷.

Many additional complaints from residents about similar incidents over many years from the red mud lakes have not been acted on by regulators due to insufficient monitoring data. However a legal class action against the alumina manufacturer is currently underway by residents in nearby towns who claim to have serious health problems as a result of their exposure.²⁸

It remains unclear how Lynas intend to prevent similar incidences from arising at their residue disposal ponds. A reference is made that the Lynas residue ponds will be covered with 'special materials'²⁹ to prevent rain ingress (presumably to hinder groundwater contamination). No details are provided as to the nature of this material or whether the operational state of the ponds will be 'wet' or 'dry'. Dry residue containment has a high risk of dust generation while wet storage (submerged tailings) has a high groundwater contamination potential.

Groundwater contamination

The potential for groundwater contamination to arise from tailings disposal ponds is also high. The two most common means by which groundwater contamination can result from tailings ponds are a) structural failure and b) leakage.

Structural failure

The structural failure of a tailings pond can arise through poor construction, incompatible materials, waste overloading, age, natural events (earthquake, landslides, flooding, and heavy rain) or a combination of the above.

While not all mining tailings pond failures are recorded or known to authorities some Non Government Organisations (NGOs) compile databases on these events. The World Information Service of Energy (WISE) Uranium Project is one such database³⁰ that provides a chronology of major tailings pond failures since the 1960's including mining wastes from uranium processing and tailings that contain uranium such as LAMP waste.

Of particular note is the massive failure of the MAL Magyar Aluminium red mud ponds in Kolontár, Hungary on October 4, 2010. The failure of the tailings ponds released 700, 000 m³ of red mud resulting in several towns

²⁷ Accessed at <http://www.perthnow.com.au/business/business-old/alcoa-admits-wagerup-dust-breach-of-operating-licence/story-e6frg2qu-1225909451999>

²⁸ Brueckner., M, and Ross., D (2010) *Under Corporate Skies: A struggle between people, place and profit*. Fremantle Press Western Australia 2010

²⁹ op cit. 15 at 46

³⁰ Accessed at <http://www.wise-uranium.org/mdaf.html>

flooded, 10 people killed, around 120 people injured and 8 square kilometres flooded with caustic mud containing toxic heavy metals and radionuclides. The reason for the failure was shear failure of the northern embankment of the tailings ponds³¹.

The LAMP tailings ponds may be particularly vulnerable to collapse due to a number of local geotechnical and environmental features of the proposed site. The Gebeng area has a very high annual rainfall in excess of 3000mm and a comparatively low evaporation rate of around 1000mm per year.³² This will result in large volumes of water falling on the tailings ponds raising the risks associated with pond failure, leakage and overflow.

Engineering consultants Worley Parsons have raised concerns about the high risks associated with these high rainfall conditions as it *suggests that residues disposed as a wet slurry will not readily densify. The high phreatic surface³³ resulting from this presents a serious risk of critical tailings failure / overflow.*³⁴

Worley Parsons also warn that if this (tailings ponds) were to become the preferred option it would require detailed geotechnical design and seismic hazard evaluation. The last significant earthquake in Malaysia was a 4.5 magnitude quake north of Sabah on September 04, 2009.³⁵ However, earthquakes in nearby regions have also led to seismic activity including tremors in Malaysia.

In addition to high rainfall, low evaporation rates and seismic hazards the tailings ponds are to be situated on a site with extremely poor geotechnical stability. The industrial site in Gebeng consists of clayey sandy fill over very soft swampy clays with logs and branches interspersed. Excavations into the site resulted in groundwater filling trenches to 1 metre below the surface level.

This combination of soft clays and waterlogged soils creates a high risk of liquefaction of the subsurface soils in the event of a significant earthquake. The LAMP tailings ponds are highly unlikely to maintain their integrity and contain the wastes under these circumstances.

Lined tailings ponds are not impermeable

The LAMP tailings ponds have been described as 'double-lined'. In engineering terms this translates to a compacted clay layer over normal surface soil with a High Density Polyethylene (HDPE plastic) liner sitting on top of the compacted clay. This double lined system is alleged to make the tailings ponds containing the radioactive tailings impermeable.

³¹ Accessed at <http://www.wise-uranium.org/mdafko.html>

³² Worley Parsons (2008a) *Lynas Malaysia Sdn Bhd. Lynas Advanced Materials Project. Preliminary Comparison of Residue Disposal Options*. p.8

³³ The free surface of water seeping at atmospheric pressure through soil or rock.

³⁴ op cit. 32 at 8

³⁵ United States Geological Survey accessed at http://earthquake.usgs.gov/earthquakes/eqarchives/last_event/world/world_malaysia.php

However current and historical data about these systems reveals that these systems frequently leak contaminants from the moment they have waste dumped on them and that virtually all 'double-lined' systems will leak as they age. Most systems have a projected life span of around 50 years before complete failure. This is completely inadequate for materials which have to be contained for several hundred years due to elevated radioactivity levels.

A 1990 examination of the best available landfill liners concluded that brand-new state-of-the-art liners of high density polyethylene (HDPE) can be expected to leak at the rate of about 20 gallons per acre per day (200 litres per hectare per day) even if they are installed with the very best and most expensive quality-control procedures.³⁶

There has been little improvement since the 1990's if judged against the tailings liner performance of the Lynas rare earth mine tailings pond at Mt Weld in Western Australia. The Western Australian Department of Environment and Conservation (DEC) have estimated that Lynas' recently constructed tailings pond with double liner system (HDPE and clay) will leak at the rate of *up to 14,000 litres per day*³⁷. This equates to approximately 5 million litres per year of contaminated leachate entering the ground beneath the tailings pond *under the best possible circumstances*.

The tailings pond at Mt Weld, Western Australia is much smaller than those proposed for the LAMP tailings pond. If the same design is used then the rate of contaminated leachate flowing from the ponds will be much higher due to the higher surface areas and waste volume pressure and inclusion of solvents.

The proposed tailings ponds will also contain other process waste including residual solvents from the separation process. Some of this solvent waste will be entrained with the tailings. The separation process involves the use of solvent 596, solvent 184 (Trichloroethylene or TCE) and kerosene.

Diluted solvents including Trichloroethylene (TCE) have been reported to penetrate the plastic liners of tailings ponds in days or weeks³⁸ leading to potential groundwater contamination almost from the moment that the ponds are commissioned. Even an HDPE sheet 100 mm thick is penetrated by solvents in less than two weeks³⁹. The HDPE sheets to be used at the LAMP tailings ponds will be 2mm thick.

³⁶ Bonaparte., R and Gross, B., (1990) "Field Behaviour of Double-Liner Systems," in Rudolph Bonaparte (editor), WASTE CONTAINMENT SYSTEMS: CONSTRUCTION, REGULATION, AND PERFORMANCE [Geotechnical Special Publication No. 26] (New York: American Society of Civil Engineers, 1990), pgs. 52-83.

³⁷ Department of Environment and Conservation (2011) Environmental Assessment Report. Mt Weld Rare Earths Project October 6, 2011. Western Australia.

³⁸ Park, J.K., Sakti, J.P. and Hoopes, J.A. (1996) "Transport of Organic Compounds in Thermoplastic Geomembranes. I: Mathematical Model," Journal of Environ. Engr., 122(9):800-806

³⁹ *ibid*

Large quantities of kerosene are intended for use in the solvent extraction processes of the LAMP and a residual fraction of this petrochemical will be included in the waste stream to the tailings ponds. Kerosene is generally an alkylated naphthalene group of molecules which will have similar properties to BTEX and similar impacts on a HDPE liner.

Inadequate waste disposal capacity and alternative uses for tailings

The LAMP tailings pond designs that have been submitted to Malaysian authorities have only enough capacity for 6 years of process waste despite the LAMP plants operational life of 10-12 years.

A presumption is made in the Lynas' EIA documentation that alternative uses will be found for the tailings waste such as selling the waste to other industries as process feedstock. The suggested alternative uses include building products such as cement and plasterboard as well as agricultural products such as fertiliser and soil conditioner. The assumption that the tailings waste will have an economic value is extremely optimistic given the low demand for this sort of waste material on a global scale. It is unacceptable that Lynas is seeking operational approval for the LAMP plant when it has barely enough waste storage capacity for the first half of the LAMP life⁴⁰. There is no provision made for the millions of tonnes of waste that will be produced in the second half of the LAMP operational life.

Experience has shown that finding a market for mineral processing waste is difficult because the waste may contain some useful and valuable elements but these are frequently bound up with toxic or radioactive elements that make other uses hazardous to workers, consumers of the final product or the environment.

Tailings in building and agricultural products

For comparative purposes it is useful to consider the attempt to make house bricks out of the red mud tailings from alumina production in Western Australia. As mentioned earlier red mud has similar qualities to the LAMP tailings but with a lower concentration of radioactive uranium and thorium and their decay products.

In February 2002, award-winning investigative reporter Michael Southwell exposed an experiment that went horribly wrong using red mud to make house bricks for the construction of residential homes⁴¹. The alumina producer has been trying for decades to find a way to make use of its red mud as construction products or as an agricultural 'soil amendment'.

The bricks were used in the construction of a number of houses for company workers at a number of locations that have never been revealed (though most sources suggest the houses are in the town of Waroona south-west of Perth).

⁴⁰ op cit. 12 at 20.

⁴¹ op cit. 10 at 3.

Tests by the Western Australian Department of Health found that the bricks made the houses too radioactive for human habitation and no houses were ever permitted to be made from the substance.

Attempts were made by the same company to release the red mud as a form of soil amendment for properties in the south west of Western Australia from 1991-1994. The government gave permission for limited trials applying red mud to farm land in the Peel Harvey district. After a short time farmers refused to accept any more of the material as evidence emerged of the toxic compounds it contained and livestock on the farms began to experience unusual sicknesses and death⁴². The state government has never given final permission for red mud to be used as soil amendment following the controversy over the trial.

Inadequate LAMP waste disposal plans

Consultant engineers to Lynas, Worley Parsons, have made it clear that the current planning for waste disposal at the Gebeng site is inadequate⁴³ and list a range of issues that have not been resolved including:

- failure to provide for 10 years waste storage (current plans limited to six years)
- lack of knowledge about the long term physical behaviour of the waste
- inadequate geotechnical investigations of the proposed waste disposal site
- lack of hydrogeological investigations at the site and the potential problems with high groundwater levels
- current soil conditions at the site inadequate to prevent seismic damage to the tailings ponds.
- current size of tailings ponds and surface water retention ponds inadequate to manage monsoonal rains
- local soils of too poor a quality to construct base and embankments of tailings ponds.

These concerns are reflected by the International Atomic Energy Agency who assessed some aspects of the LAMP operation and found that there was no adequate provision made for the long term storage of radioactive waste at the site. Among its 11 recommendations the IAEA was critical of the lack of long term waste management plans for the site including the monitoring of the radioactivity levels at the site.

The IAEA was emphatic that *the AELB should require Lynas to submit, before the start of operations, a plan setting out its intended approach to the long term waste management, in particular management of the water leach*

⁴² Ryle, G., (2002) *The great red mud experiment that went radioactive*. Sydney Morning Herald. May 7, 2002. Also available online at

<http://www.smh.com.au/articles/2002/05/06/1019441476548.html>

⁴³ op cit. 32

*purification (WLP) solids after closure of the plant, together with a safety case in support of such a plan.*⁴⁴

Process Liquor Contamination

Serious concerns have been raised by current and former engineers and component suppliers to the LAMP regarding the integrity of the construction of the plant itself. Some of the construction inadequacies are reported to be so serious that they could result in catastrophic failure of major vessels containing process liquors.

On June 29, 2011 the New York Times reported that current and former engineers working on the LAMP provided them with emails, memos and photos from Lynas and its contractors detailing structural cracks, air pockets and leaks in many of the concrete shells for 70 containment tanks that would hold process liquors.

Engineers were critical of the decision to build the tanks (which would hold high strength acids and radioactive concentrate);

'..Using conventional concrete, not the much costlier polymer concrete mixed with plastic that is widely used in refineries in the West to reduce the chance of cracks....'

Memos also show that Lynas and UGL have pressed a Malaysian contractor, Cradotex, to proceed with the installation of watertight fiberglass liners designed for the containment tanks without fixing the moisture problem and with limited fixes to the walls.

But Cradotex has resisted.

*"These issues have the potential to cause the plants critical failure in operation," Peter Wan, the general manager of Cradotex, said in a June 20 memo. "More critically the toxic, corrosive and radioactive nature of the materials being leached in these tanks, should they leak, will most definitely create a contamination issue."*⁴⁵

The article goes on to detail other concerns including manufacturers refusing to allow or certify their products to be used in the LAMP due to the structural problems with concrete tanks. The integrity of the LAMP foundations has also been called into question. As noted earlier the LAMP is being constructed on unstable reclaimed swampland with a high water table. According to Bradsher of The New York Times,

⁴⁴ op cit. 24 at 4

⁴⁵ op cit. 1

'Memos show that the refinery's concrete foundations were built without a thin layer of plastic that might prevent the concrete pilings from drawing moisture from the reclaimed swampland underneath. The site is located just inland from a coastal mangrove forest, and several miles up a river that flows out to the sea past an impoverished fishing village. An engineer involved in the project said that the blueprints called for the plastic waterproofing but that he was ordered to omit it, to save money.'

The serious nature of the claims by these engineers and the documentary evidence provided casts considerable doubt over the safety of the LAMP and its ability to avoid major environmental contamination as the result of a critical process failure.

It is clear that no licence should be issued for the LAMP to operate until all of the issues related to the long term management of LAMP waste and construction inadequacies have been resolved. The issue of the pre-operating licence by the AELB on February 2, 2012 ignores this fundamental requirement and places the environment and public health at serious risk.

Air emissions

Air emissions from the stacks of the LAMP plant include a range of hazardous pollutants including hydrogen fluoride (HF), silicon tetrafluoride (SiF₄), silicon hexafluoride (SiF₆), sulphur trioxide (SO₃), sulphur dioxide (SO₂) sulphuric acid (H₂SO₄), oxides of nitrogen (NO_x) and fine particulate (including alpha radiation emitting particles).

While these pollutants are mostly acidic in nature and can lead to severe respiratory problems among exposed humans, Lynas are claiming to use state of the art pollution scrubbers to filter out most of the pollutants before they reach the atmosphere through the stack.

While this is theoretically achievable during optimum plant operation conditions with scrubbers working at their highest efficiency, it is unlikely to represent the reality of the operation where plants rarely operate at optimum efficiencies .

By their nature air pollution scrubbers such as wet sprays (wet scrubbers) electrostatic precipitators (for particulates and dust), baghouses (for dust capture) and cascading lime scrubbers (which inject lime into flue gas to neutralise acids) decrease in efficiency as they clog with contaminants that are filtered out of the flue gas.

Electrostatic precipitators (ESP's) shut down in the event of power outages allowing the full concentration of pollutants to pass through them unless the section of the plant they operate in is also shut down. Many companies simply keep operating until specialists come to repair the ESP or replace it.

Baghouses can be highly efficient at removing dust but decrease in efficiency rapidly unless they are carefully maintained and cleaned at all times. The filter cake that is removed from the baghouse filters during cleaning can be highly hazardous due to the concentration of pollutants that are gathered in the filter and stripped from the flue gas. Any tears or burning of the filters can allow large amounts of pollution to escape. It is also anticipated that the 'filter cake' and other solid waste gathered in the pollution scrubbers will be disposed of in the tailings ponds with the process wastes. This practice can lead to a range of dangerous chemicals entering the tailings ponds with the potential to leak and pollute groundwater.

It is common for water monitoring programmes to overlook the presence of these dangerous chemicals when sampling regimes are developed. There is a tendency to only test for a limited range of contaminants that are known to be in the tailings and scrubber waste chemicals and heavy metals can be overlooked. If the tailings ponds leak, these chemicals can go undetected for years.

The acid gases that are expected to be released through the stacks of the plant can lead to serious health effects at sufficient concentrations. The acid gases attack the mucosal linings of the human respiratory tract and eyes aggravating existing ailments such as asthma.

The LAMP plant will emit silicon tetrafluoride (SiF_4) which may be fatal if inhaled, ingested or absorbed through skin. Vapours are extremely irritating and corrosive. Contact with its gas form or liquefied gas may cause burns, severe injury and/or frostbite. However, the emitted silicon tetrafluoride vapours are decomposed exothermically by water or moisture in the air to hydrofluoric acid (HF).

HF is a very powerful corrosive gas and exposure can lead to severe breathing difficulties. HF emissions from brickworks near Perth in Western Australia have caused serious damage to vegetation, in some cases destroying vineyards. One primary school was also closed in the 1980's in the Swan Valley because the emissions of HF from a nearby brickworks caused respiratory problems in students and teachers including asthma and acute nose bleeds. HF is so powerful that its presence in the atmosphere can cause etching of glass windows.

Environmental effects of acid gases are well known and can lead to localised 'acid rain' which can damage crops and acidify freshwater bodies such as lakes and streams. Acid gas emissions must be carefully monitored with 'real-time' data on stack emissions being made available to regulators and the public via the company or regulators website.

Many industrial licences allow 'bypass' conditions for a number of times per year whereby a plant can bypass its scrubbers due to operational problems and release the full load of flue gas emissions to be emitted to air without any filtering. Under these circumstances very high levels of pollution can be

released for hours or days exposing the local population to peak levels of pollution.

The Lynas EIA reports fail to detail the control mechanisms for NO_x, or Volatile Organic Compounds (VOC's). NO_x may get generated from the combustion process as the temperatures are relatively high for calcining of the lanthanum oxide. No detail is provided on nitrogen containing compounds in the calcined ore. A good proportion of the NO_x is likely to be scrubbed out in Stage 2 of the scrubbing circuit, but that depends of design and efficiency of that process. Some of the NO_x compounds are poorly scrubbed by any form of wet scrubbing leading to significant atmospheric emissions.

NO_x is formed when certain fuels (oil, gas and coal) are burned at a high temperature, such as in combustion tunnels (rotating trommels) which will be used to calcine the lanthanum oxide. In terms of human health small levels of NO_x can cause nausea, irritated eyes and/or nose, fluid forming in lungs and shortness of breath. Breathing in high levels of NO_x can lead to: rapid, burning spasms; swelling of throat; reduced oxygen intake; a larger build-up of fluids in lungs and/or death.

According to the USEPA VOC's exposure can lead to a range of health effects including:

*Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.*⁴⁶

The use of chemicals in the solvent extraction process at the LAMP (such as TCE), indicate that large quantities of VOC's will be present in the manufacturing process. VOC's are highly volatile and can partially convert to a vapour form at room temperature. Generally speaking, the higher the process temperatures the higher the rate of volatilisation of the solvent. There is virtually no data in the EIA on how these VOC's emissions will be controlled.

The lanthanum oxide tunnel furnace will not just emit CO₂ and H₂O. It is also likely to be a source of NO_x and carbon monoxide (CO) as a result of the higher temperatures. According to the USEPA;

Carbon monoxide is an odorless, colorless and toxic gas. Because it is impossible to see, taste or smell the toxic fumes, CO can kill you before you are aware it is in your home. At lower levels of exposure, CO causes mild effects that are often mistaken for the flu. These symptoms include headaches, dizziness, disorientation, nausea and fatigue. The effects of CO

⁴⁶ [http://www.epa.gov/iaq/voc.html#Health Effects](http://www.epa.gov/iaq/voc.html#Health%20Effects)

*exposure can vary greatly from person to person depending on age, overall health and the concentration and length of exposure.*⁴⁷

The lanthanum oxide tunnel furnace will also generate particulates which will be of significant concern due to the high potential for radioactive particles of uranium and thorium and decay products to escape to atmosphere. As explained earlier in this report the inhalation of alpha emitting radioactive particles represents a much higher risk to the individual than external exposure by gamma radiation in the context of the LAMP plant. This internal exposure includes inhaled wind blown particles from the tailings pond, lanthanum concentrate stockpile and stack emissions. No data is given in the EIA documents on the expected levels of particulate emissions from the calcining furnace or other sources at the LAMP.

While most of the air emission issues discussed above relate to stack emissions or fugitive emissions from stockpiles and tailings there are also risks for workers and the public associated with the use of kerosene and solvent used in the extraction processes.

The risk assessment documentation by DNV⁴⁸ only examines the scenarios involving the storage and transfer of kerosene to the solvent extraction section of the plant. The risk arising from static induced fires in the extraction train is not assessed. This is a high priority for risk assessment as other facilities using similar processes have suffered enormous financial losses (in excess of A\$300m) due to massive fires in the solvent extraction train.

The Olympic Dam uranium processing facility in South Australia has experienced two large static induced solvent extraction fires in 1999 and 2002. While these operations occurred in remote areas and residents were not exposed to the emissions, a fire scenario of this nature at Kuantan could impact on local population through toxic vapours and destruction of key plant storage and process infrastructure. This key risk vulnerability must be assessed before the plant is operational.

DNV also indicate that large quantities of sodium sulphide will be used in the LAMP process. Great care must be taken to ensure that absolutely no acidic medium will come in contact with this chemical or the reaction will result in the release of hydrogen sulphide, an extremely hazardous, toxic compound.

It is a colourless, flammable gas that can be identified in relatively low concentrations, by a characteristic rotten egg odour⁴⁹.

At concentrations above 100 ppm, a person's ability to detect the gas is affected by rapid temporary paralysis of the olfactory nerves in the nose, leading to a **loss of the sense of smell**. This means that the gas can be

⁴⁷ <http://www.epa.gov/iaq/co.html>

⁴⁸ Det Norske Veritas (2010) Technical Report. Quantitative risk assessment study of Proposed Advanced Materials Plant within the Gebeng Industrial Estate, Kuantan, Pahang. Report No. EP029020 Rev 2.

⁴⁹ http://www.safetydirectory.com/hazardous_substances/hydrogen_sulfide/fact_sheet.htm

present at dangerously high concentrations, with no perceivable odour. Exposure to levels of 50 - 200 ppm can lead to;

- Severe respiratory tract irritation
- Eye irritation / acute conjunctivitis
- Shock
- Convulsions
- Coma
- Death in severe cases

In the enclosed environment of the LAMP any major release of hydrogen sulphide is likely to lead to fatalities among workers if they cannot escape the facility rapidly. The use of copious volumes of acid in the process significantly raises the risk of a chemical reaction.

In terms of stack emissions the LAMP will be required to meet the Standard C limits of the Environmental Quality (Clean Air) Regulations, 1978 and the radioactive discharge limits approved by the AELB⁵⁰. Details for limits of individual air pollutants are also noted at page 5-66 of the Environ report.⁵¹ Lynas also concede that ambient air limits will be breached under emergency conditions but claim that the chances of such conditions occurring are remote.

The reality is that process malfunctions and electrical trips can result in regular bypass of scrubbing equipment effectively mimicking 'emergency conditions'. The frequency of 'emergency' releases from similar facilities in Australia is relatively high and is likely to occur a number of times during the operation of the LAMP.

It is also of great concern that Malaysian regulators permit SO_x, NO_x and PM 10 levels that are much higher than WHO guidelines⁵². The more lenient pollution regulations are detailed at Table 5.6.1 *Recommended Malaysia Air Quality Guidelines*, Environ (2010).⁵³

Without detailed and accurate atmospheric modelling *calibrated by data from field monitors* it will be impossible to determine the impacts of LAMP air emissions on the environment and the public. As an absolute minimum, Lynas should have provided the detailed air modelling for atmospheric emissions of each major chemical pollutant. This would have been a pre-requisite for EPA assessment in Australia.

⁵⁰ op cit. 15 at 27

⁵¹ Environ (2010) Preliminary Environmental Impact Assessment and Quantitative Risk Assessment of the Proposed Advanced Materials Plant within the Gebeng Industrial Estate, Kuantan, Pahang, Malaysia.

⁵² World Health Organisation (2000), Guidelines for Air Quality.

⁵³ p.5-64

Wastewater disposal

While the final water quality discharge criteria for the LAMP are not yet available (the AELB will determine uranium and thorium discharges) it is likely that this form of disposal will lead to significant environmental impacts. The preliminary standards to be used for wastewater before it is discharged to the Balok River are *Standard B of the Environmental Quality (Sewage and Industrial Effluents) Regulations. 1979 (Schedule 3)*. Individual analyte limits are detailed in Table 5.2.1 of Environ (2010)⁵⁴. Wastewater will be discharged from the LAMP at the high rate of 500m³ per hour⁵⁵. If the wastewater treatment plant fails the rate will increase to 700m³ per hour with a higher pollutant loading.

The Standard B limits are poor in that they permit up to double the level of Standard A for BOD and COD with heavy metal discharge limits between 5 and 10 times higher than standards A limits. The wastewater discharged will have much greater environmental impacts than if Standard A was adopted.

Unfortunately these water pollution standards do not include key pollutants from the processing of rare earth such as uranium and thorium, solvents such as trichloroethylene, total petroleum hydrocarbons or fluorides.

Nuklear Malaysia states that the AELB is yet to set radioactivity limits for discharges to the river.⁵⁶ It is critically important to assess the role of the chemicals involved in the production of rare earths and to assess their individual ecotoxicity characteristics and human health risk impacts arising from the consumption of biota from the Balok River and around its discharge point into the ocean. Contaminants will be carried down river in heavy rains and accumulate in the sediment in the coastal areas near the mouth of the river.

In a recent report on rare earth refining by the USEPA it was noted that;

*“Chemicals and compounds used during refining could contaminate the environment too. Extreme care must be used in handling all the materials associated with rare earth element production to ensure they are not released into the environment.”*⁵⁷

In the case of the LAMP plant these chemicals will be released into the Balok River after preliminary wastewater treatment. However due to the omission of key contaminants in the regulations, the operating licence may not require any monitoring or discharge limits for some of the key contaminants. This could

⁵⁴ op cit. 51 at 5-3

⁵⁵ ibid at 5-27

⁵⁶ op cit. 15 at 27

⁵⁷ Paul, J., and Campbell, G., (2011) *Investigating Rare Earth Element Mine Development in EPA Region 8 and Potential Environmental Impacts*. USEPA EPA Document-908R11003 p.12

lead to serious pollution without any legal responsibility by the company to act on the contaminants as they are not a controlled substance under the licence.

Standard B of the regulations does allow elevated levels of heavy metals such as mercury, lead and arsenic to be discharged to the river which will accumulate in the sediment of the river over time. The impacts on the Balok River system of this pollutant loading are unknown as the baseline studies of the river ecosystem, contamination levels and cumulative impacts from other industries has not been presented in the EIA documents by Lynas as would be expected in other jurisdictions such as Australia, the US or Europe. While some references are made in the Lynas EIA documents to other polluters causing elevated COD levels in the Balok River there is no comprehensive modelling of the impact of treated or untreated wastewater from the LAMP on the Balok River.

Liquid effluent discharges to river systems and lakes has been discontinued in many developed countries due to the lack of adequate dilution and mixing effects that may be encountered in surface water or marine discharges.

While hazardous contaminants in the wastewater such as heavy metals and persistent organic pollutants may not immediately lead to fish kills or other obvious problems, the concentration of these poisons in the river sediment can lead to elevated levels of contamination in the flesh of fish. In turn, this represents a significant public health threat to locals who consume aquatic creatures from the river or its discharge point to the ocean. Similarly the build up of contaminants within sediment can contribute to biomagnification or bioaccumulation of persistent organic pollutants within aquatic and marine organisms exposed to the wastes from the LAMP plant via the Balok River.

In addition to chemical loads, discharges must be controlled by maximum biological oxygen demand (BOD) and chemical oxygen demand (COD) license limits to prevent oxygen starvation of aquatic life. Excessive BOD and COD will lead to sterile zones in a river system and the death of most oxygen dependent river organisms within those affected areas. The COD and BOD limits permissible under Standard B of the regulations are twice the level permitted under Standard A. These are the *least stringent* limits that the Malaysian regulators can apply.

The limited modelling conducted by Lynas⁵⁸ indicates that COD discharge levels in treated wastewaters will be high and may at times exceed regulatory limits. Levels of COD in the Balok River are already approaching the Class III water quality threshold limits as a result of other pollution sources discharging to the river. The additional contribution from Lynas could overload the ecological capacity of the river and damage river biota.

It should also be noted that as anaerobic conditions increase in the Balok River due to higher COD and BOD and reduced oxygen, levels of heavy metal contaminants such as arsenic and mercury will rise due increased due to

⁵⁸ Op cit 51 at p.5-26

increased solubility. Mercury can then transform to methylmercury (a particularly toxic form of mercury) that accumulates in fish and other aquatic biota which, in turn, may be consumed by fishermen, local residents or sold on the open market.

While the final discharge limits for the LAMP plant are uncertain it is clear that radiation and heavy metal levels in the river will rise following the operation of the plant. There are also major concerns that many chemicals that will be part of the waste stream from the LAMP plant do not fall under the Malaysian effluent regulations and are likely to be discharged to the river in an uncontrolled and undetected manner.

The LAMP plant should not be permitted to operate until the ecological and public health impacts of effluent release to the Balok River have been modelled and assessed in detail. The modelling should include ecotoxicology assessment on endemic biota, food web assessment and a quantitative analysis of human health impacts from river users and consumers of aquatic biota. Long term cumulative impacts of heavy metals upon the Balok River including uranium and thorium must be assessed prior to release of any wastewater. The lack of data on these issues renders the Lynas EIA well below international standards and insufficient for granting of operational licences.

Please note this information is provided as general information and comment should not be seen as professional advice