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The Role of Universiti Malaysia Pahang (UMP) In Human Capital Development for The Mineral Resources Industry: Rare Earth Case Study

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Abstract

The demand of 'Rare Earth Elements' (REE) from key industries such as electronics, mobile technology, renewable energy as well as defence sectors have increased rapidly in the last decades. In fact, Malaysia is estimated to contain around 30000 metric tonnes of REE and this is a new growth area for Malaysia especially in the downstream extraction and purification processing of Heavy Rare Earth Element (HREE). Understanding this opportunity, Universiti Malaysia Pahang (UMP) has proactively took an initiative by establishing an entity which known as Rare Earth Research Centre (RERC). Moreover, in this light, UMP has also taken another critical step to particularly facing the challenge of establishing rare Earth Industry (REI) by initiating the first ever master degree in Mining and Mineral Technology (MMT). The main aim of this course is to promote a comprehensive program that supports to the activity of 'sustainable mining' which covering the whole spectrums of 'cradle-to-grave' phases. The basic idea behind this initiative is to ensure that mine operators and the stakeholders are aware about the future needs for responsible and sustainable mining industries.

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Key Words: *Rare earth industry, UMP, mineral resources management*

1. INTRODUCTION

Universiti Malaysia Pahang (UMP), which formerly known as Kolej Universiti Kejuruteraan & Teknologi Malaysia-KUKTEM, was established by the government of Malaysia in 2002 with the aim of adopting the traditional engineering education culture of Fachhochschule model of Germany. The essence of its primary functionality, in which to pursue on the technical-based curricular, makes it a prominent higher learning institution of the eastern corridor of Malaysia that possesses a specific important role particularly in strengthening the human capital development towards industrial needs. For instance, the issue of establishing Lynas Advanced Materials Plant (LAMP) in Gambang Pahang that took place back in the period of 2012-2013, depicts UMP as the main platform for both the community and industry to seek consolidation and eventually finding the resolution for mutual benefit. In this context, UMP has engaged with the relevant shareholders in spreading the truth that underlies the issue particularly to highlight that LAMP is a typical chemical processing plant that processing rare earth mineral extraction and not related to any of nuclear reactor operation. As a result of Parliament Senate Committee (PSC) resolution, by 2014 UMP has proactively took an initiative by establishing an entity which known as Rare Earth Research Centre (RERC) in encouraging any of R&D activities on Rare Earth Industry (REI) that specifically based on mineral resource in Malaysia. This scenario has shown that academia can play a specific role and delivering high impact of resolving industrial issue provided that the academic freedom as well as its corresponding ethical principles are allowed to be practised without prejudice. The following paragraphs explain the conceptual framework of developing rare earth industry within the context of Malaysia and the specific role of UMP for that purpose.

2. RARE EARTH CHALLENGES

The demand of 'Rare Earth Elements' (REE) from key industries such as electronics, mobile technology, renewable energy as well as defence sectors have increased rapidly in the last decades. However, the extraction of REE from its primary source is a challenging task. Since 1980s, China has consistently dominated in the production and reserved mineral stock as compared to other countries. Thus, the competiveness of global REE market is greatly depending on the trade policy of China (Binnemans, et al., 2013). Meanwhile, the mainland China is badly facing the serious environmental issues due to poor industrial REE practise and loose enforcement control (Humphries, 2013). Hence, it is debateable that the gravely hunger of China's REE demand may eventually jeopardizing the REE industry as a whole, and thus, developing the complete REE supply chain outside China is highly desirable.

In this light, the world REE market can be perceived to be at the stake of susceptibility for all spectrums of REEs. In addressing the issue, various European countries as well as US has identified that certain components of REES such as Neodymium (Nd), Europium (Eu), Terbium (Tb), Dysprosium (Dy) and Yttrium (Y), may suffer from major supply restrictions in the near future (US DOE, 2011). This limitation could eventually induce huge spike in price increments of those REEs which was experienced back in 2010-2012 period. If this prevails for a longer time, then sustaining the economic benefits of REEs-driven products is almost impossible. Hence, there is a need in recovering the REE from alternative sources (such as e-waste or industrial waste/mining tailings) instead of depending on the primary mining in order to sustain the supply.

A comprehensive review on the advantages and challenges of REE recovery from the secondary resource has been discussed thoroughly in Binnemans, et al., (2013) as well as Tsamis and Coyne (2015). In general, there are three main pathways of recovering REE – pre-consumer scrap, urban mining and also landfill mining or industrial waste. For instance, Malaysia has been struggling with the issue of excessive bauxite mining since 2015. From the literature, it is generally known that REEs are also available within the bauxite minerals and there are three (3) main sources of it - whole rock, pure kaolinite and high organic kaolinite (Ling, et al., 2015). Among of the three, the high organic kaolinite contains mostly the valuable REE which accumulated to around 4 grams in total for every kilogram of bauxite. In 2015, the bauxite mineral was exported from Malaysia directly to China with the capacity of 35 million tonnes. Considering the price is USD 29 per tonne, the total revenue that contributed by trading the bauxite ore alone is approximately around 1 billion of USD. In contrary, recovering of selected critical REE from the bauxite ore will generate in revenue of 3.5 billion of USD based on the same export capacity. This equivalent to 300 percent increment in profit revenue compared to the ore trading of 2015. All these figures suggest that there is a huge fortune which can be explored widely particularly in REE recovery activity that focusing on the secondary resource.

Another potential of recovering REE from alternative resources is through electronic waste (e-waste). E-waste is generally composed of all kinds of electrical or electronic goods which are at the end-of-life term. Even though, these are in a very small proportion per item, but all these devices also contain significant quantity of precious metals such as gold and silver as well as critical/valuable materials including REE. At the same time, the useful life of electrical and electronic equipment (EEE) has been shortened as a consequences of the advancement in technology and change in consumer patterns around the world (Khaliq et al., 2014). This resulted in generation of abundance of electronic waste (e-waste) that needs to manage and treat properly. The handling of e-waste including the combustion in incinerators, disposing in the landfilled or exporting to the outside of country which eventually lead to environmental pollution. It is estimated that 2.3 million tons of electronics were discarded, whereby merely 25% was recycled (Cho, 2012). Figure A depicts the amount of e-waste from PC's units and weightages that expected to be generated from Malaysia for the period of 2016-2020 while Figure B indicates the available mass capacity of selected REEs from PCs.

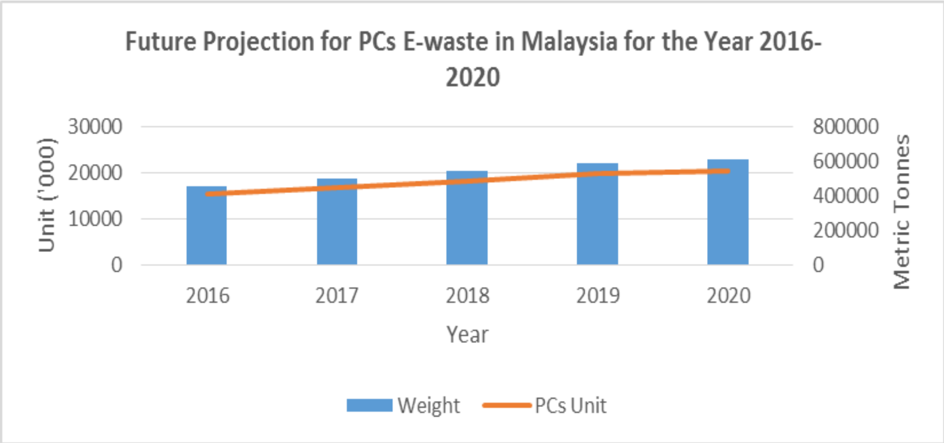

Figure 1: Future projection for PCs E-waste in Malaysia for the Year 2016-2020 (DOE Malaysia and Ex-Corporation Japan, 2009)

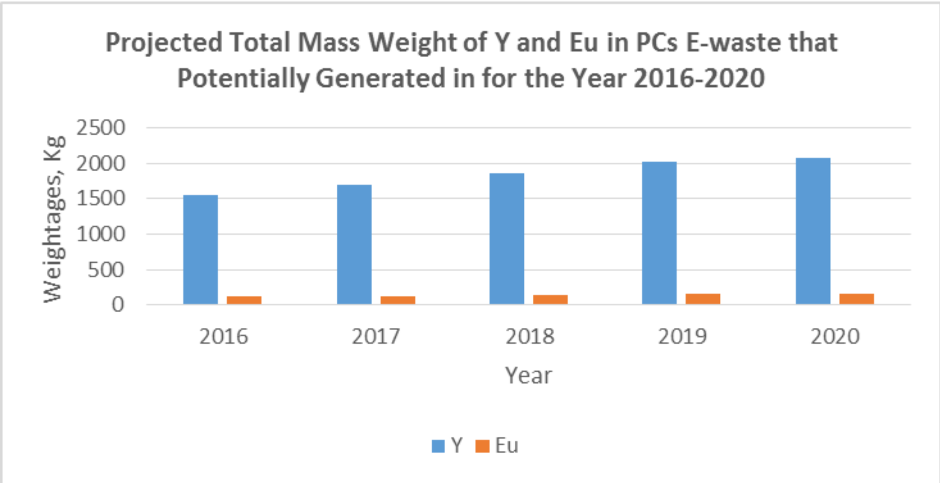

Figure 2: Projected total mass weight of Y and EU in PCs E-waste that potentially generated for the year 2016-2020 in Malaysia

It is estimated that, the amount of PCs that generated in the E-waste stream of Malaysia will consistently increase from 2016 to 2020 and assumed to be more than 15,000 units annually (Figure A). Also, it is proposed that the accumulated PCs and its equivalent total mass can reach approximately to 90,000 units and 3,000 metric tonnes respectively. Accordingly, the total mass weights of Y and also Eu elements that can be potentially extracted are around 9000 kg and 700 kg respectively (Figure B). Thus, nearly 300,000 and 100,000 USD expected to be gained from both REE elements in next 5 years. In addition, fifteen other RE components are available which can be stripped out from the scrapped PCs. This initial analysis is based on the PCs, whereas all the components of REE can be utilised from the consumer electronics, such as laptops, mobile phones, LCD/LED TVs, hybrid car battery and refrigerators. All these may roughly contribute to the additional of hundred millions of USDs, on top of what have gained through PCs alone.

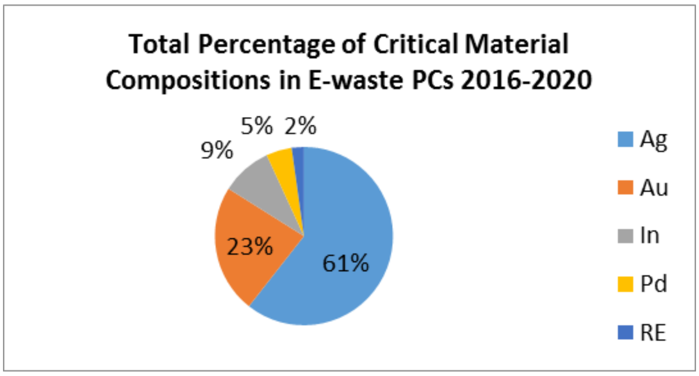

Figure 3: Total Percentage of Critical Material Compositions in E-waste PCs 2016-2020

Nonetheless, in the context of REEs scenario, relative quantification as well as pricing should not be treated as the major factors because these are relatively low as compared to those valuable components. The relative amount of mass weightage percentages that potentially generated through e-waste of PCs based on the critical material group including REEs for 2016 -2020 in Malaysia is denoted in Figure C. Obviously, the amount of REE is the smallest; however, the data is solely indicating the PCs as the source of e-waste. In this context, the significance of REE contribution on its primary utilization for various critical sectors such as defence technologies including laser, super magnet, wind turbine, phosphors and radar should be seriously realized. Thus, stockpiling of these REEs domestically are not only essential for initiating the complete supply chain outside China, but also important as a proactive measure to enhance the national economic survival and security.

3. MALAYSIA PROSPECT OF REI

Malaysia is estimated to contain around 30000 metric tonnes of REE. There are vast opportunities of discovering and venturing into REI and becoming a new growth area for Malaysia especially in the downstream extraction and purification processing of Heavy Rare Earth Element (HREE). Perhaps, there are two basic reasons for this. Firstly, Malaysia was one of the biggest industries in tin mining as well as iron ore in the past and therefore developing such capacity again that applied for REI would not entirely complex to the country. The basic practise of mining activities and expanding the scopes of middle-downstream processing are ready to be further enhanced in Malaysia. The second reason being is HREE is more valuable in terms of pricing. However, they are very complex to be refined as the amount is relatively low. Most of the critical metals that defined by USA for instance (US DOE, 2011), also relates mostly to the HREE. Thus, selectively developing and concentrating on a few critical HREE should be the main strategy for Malaysia. For instance, Malaysia is known rich in xenotime deposit and it is composed greatly of Y element (HREE). In contrary to monazite or bastnaside, the minerals are mostly dominated by low values of REE such as Lanthanum (La) or Cerium (Ce). Hence, Malaysia's soil is unique in a sense that makes it conducive for the HREE extraction. Many countries including Japan US and Europe are looking for strategic partnership in securing HREE for their domestic supply (USGS, 2005).

In moving forward, Malaysia needs strategic initiatives to establish the REI especially to make it sustainable and giving significant impact to the nation's economic growth. According to The Academy of Sciences Malaysia and The National Professor' Council (2011), the key strategies in strengthening such efforts should include:

- Enhance the environment, safety and health aspects of the industrial resource as well as waste management.
- Undertake a national exercise to map the potential rare earth alluvial and hard rock deposits.
- Incentivise the upstream mining and extraction of REE through partnership with global enterprise.
- Incentivise investments in the downstream manufacturing of REE.
- Build the key competence in human capital for the entire value chain.
- Strengthen the legal and regulatory framework.
- Undertake a coordinated, comprehensive and continual public awareness program.

Follow up into that, Ministry of Science, Technology and Innovation (MOSTI) Malaysia, and also, The Academic of Sciences Malaysia have jointly published the nation's blueprint particularly pertaining to the establishment of REI in Malaysia (MOSTI and ASM, 2014). The report mainly emphasizes on the importance of developing human capital sector in supporting the whole supply chains of REI (upstream to downstream phases). According to the report, at the national level, Malaysia can directly take benefit out of REI in four stages including foreign direct investment, national income, employment and government revenue. Meanwhile, it also highlights a specific role for academia that should be reinforced fundamentally which correspond to the R&D areas and syllabus improvement. The research domains which are critical for REI include (MOSTI and ASM, 2014):

- Process improvement in refining RE.
- New solid-liquid extraction methods.
- Thorium and Uranium Extraction for fuel.
- Scale up and process design study.
- Bioprocessing as an alternative to the current chemical processing.
- Sustainability assessment.

On the other hand, there are a number of areas that need to be fundamentally taught at the tertiary educational courses such as (MOSTI and ASM, 2014):

- Solid chemistry/properties.
- Combination of different ore materials.
- Urban mining.
- RE chemistry.
- Advancement in process technology.
- Unit operations.
- Separation technology.

4. UMP ROLE IN MINING EDUCATION: SUSTAINABILITY

The economic growth via mining activity obviously creates a positive impact on the affluent country but, in contrast, it does have negative implications for the environment and society, if it is not in a containment of harmonious coexistence and deflect from the need to ameliorate present sustainability of economic-environment-societal association. In this light, UMP has taken another critical step to particularly facing the challenge of establishing REI industry by initiating several courses at the bachelor and master level. The main aim of the whole courses is to promote a comprehensive program that supports to the activity of 'sustainable mining' which covering the whole spectrums of 'cradle-to-grave' phases. Moreover, there might be a few mine operators showing propensity to an egregious practice which include illegal discharging of a myriad of mining residues, uncontrolled mineral exploration and a reckless disregard for workers and neighbourhood safety. Understanding these facts, the need to develop ecologically and responsibly practice in mining activity through educational system is becoming more important. Therefore, in line with the Malaysia National Policy on the Environment, (2002) on a sustainable use of natural resources and prevention of degradation of the environment, UMP has taken the lead to proactively involve in introducing and developing the 'sustainable mining' syllabus at the master level. UMP has introduced the master degree namely Mining and Mineral Technology (MMT) through Faculty of Chemical and Natural Resources Engineering (FKKSA) with its aim to enhance the mining activity without dissociating the 3P's of sustainable development's pillars: people, profit and planet. Some of the contents which have been embedded in the syllabus are concept of responsible mining, environmental impact assessment, mine closure technologies, legislations, and mining sustainability, to name a few. The basic idea behind this initiative is to ensure that mine operators and the stakeholders are aware about the future needs for responsible and sustainable mining industries. In general, in order to achieve economical, environmental and social benefit balance, optimizing the effective management of circular economic model should be seriously considered, and that include recycling and recovery activities (Chucchiella, et al., 2015).

5. REE-BASED ACTIVITIES THROUGH RERC

RERC is formed in UMP particularly to undertake a specific role in initiating the interest of Malaysia's mineral industries as well as securing public concerns by means of R&D activities and technical services that corresponding to REE development. Currently, there are six (6) research areas that are being focused at RERC as shown in the following list (Ismail, 2017):

a) Fundamental science of REE
b) New alternative separation of REE
c) Simulation and modelling of REE
d) REE processing pilot plant
e) REE applications
f) REE Sustainability and environmental monitoring

In the period of 2014-2016, a total of twelve (12) research grants have been obtained, of which it comprises of six (6) internal grants, five (5) national grants and one (1) international grant that contributed of RM 650,000 in total. Table A shows the current R&D projects that mapped as according to the research areas of RERC:

Table A: Mapping of R&D Projects and Research Areas in RERC

R&D Projects	Research Areas in RERC					
	a	b	c	d	e	f
1. Optimization of Nd recovery processes from NdFeB permanent magnet scrap	-	√	-	-	-	-
2. Extraction of lanthanide using ionic liquid	-	√	-	-	-	-
3. Green synthesis:photo-initiated polymer dispersion polymerization	-		-	-	√	
4. Removal of chloride from rare earth industrial wastewater using bioremediation hybrid with electrocoagulation system	-	-	-	-	-	√
5. Fundamental studies of rare earth separation	√	√	-	-	-	-
6. Kinetic reaction analysis of catalytic syngas production from glycerol	-	-	-	-	√	-
7. Light rare earth oxide nanoparticles as flux pinning center to enhance critical current density in Ag-Sheathed Bi-22232 superconductors tapes	-	-	-	-	√	-
8. Kinetics and mechanistics studies of photocatalytic degradation of POME over lanthum doped calcium oxide derived from cockle shells	-	-	-	-	√	-
9. A novel biogas production from the photocatalytic degradation of POME UV-responsive-titania based photocatalyst	-	-	-	-	√	-
10. Simulation studies of rare earth extraction system	-	-	√	-	-	-
11. Develoment of real time radiological monitoring framework based on Lynas-Advanced Materials Plant (LAMP)	-	-	-	-	-	√
12. Modelling of rare earth element leaching and residual separation systems	-	-	√	-	-	-

Based on Table A, the emphasis of RERC strategy has been on the areas of 'b' (new alternative separation of REE) and also 'e' (REE applications), whereby these two R&D domains contain relatively higher number of projects in compared to others. Meanwhile, there is no specific grant that related to the area 'd' (REE processing pilot plant). This scenario simply shows that RERC is still struggling to obtain industrial partnership for further boosting the grow interest from the industrial sector. At present, there are 15 under and post graduate students are committed to the centre as well as a total of twenty (20) articles related to REE have been published, in which, 85% are ISI/scopus indexed and 50% are related to Q1 ranking. Anyway, considering that RERC has just in three (3) years in operation (2014-2016), this particular progress should be treated as sufficient, where it can sparks motivation among academia for strengthening research activities in terms of post-graduate studies and publications. Apart from the academic and R&D efforts, RERC also has contributed the country by delivering training programs and also various technical services. Table B denotes the list of successful training courses that conducted in the years of 2014-2016 by RERC.

Table B. List of Trainings Conducted by RERC in 2014-2016

Training Courses	Participants
1. Rare earth processing series 1	Officers from DOE Malaysia
2. Rare earth processing series 2	Officers from DOE Malaysia
3. One-day workshop on ASPEN	UMP students and researchers
4. Workshop on rare earth separation technology	UMP students and researchers
5. Gold mining opportunity in Malaysia	Law enforcement officers and industrial miners

The following list highlights some of the consultation works have been performed by RERC to support the REE industry in Malaysia:

a) Characterization of mineral samples using various analytical instruments
b) Development of mineral processing route
c) Optimization of metal extraction process
d) Recovery of metals from electronic waste
e) Feasibility study

All these outputs justify that UMP through RERC has delivered its best strengths to initiate and support the establishment of REE industry in Malaysia particularly within the context of human capital development by means of academic as well as R&D works, industrial services and also training programs. In moving forward, RERC in collaboration with FKKSA are embarking on large scale REE recovery activities that derived from the local waste resource. Perhaps, this initiative can create a successful 'cradle-to-grave' REE processing model and contributing towards expanding the new technology for HREE extraction.

6. CONCLUSIONS

Undoubtedly, Malaysia has a unique function particularly to spur the commercialization of REE at global market that derived from its local resource including primary as well as secondary. From the sustainability point of view, the secondary pull looks rather promising as the focus has shifted towards HREE rather than LREE particularly in the downstream processing phase. The challenge though, this vast fortune requires several of new sets and also sophisticated talents that critically to be developed in terms of human capital skills and fundamental know-how of operating sustainable mineral processing. In this context, UMP has proactively prepared to play its vital role by establishing RERC and MMT particularly to cater the whole supply chain value of REE processing, perhaps with the specialty design towards the HREE and its corresponding sustainability impacts. Perhaps, enhancing such initiative may contribute significantly to the REE industry especially for creating the alternative supply chains of REE trading outside China.

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