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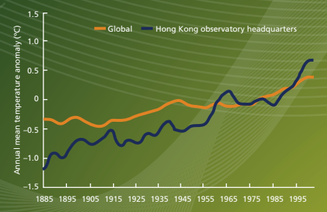

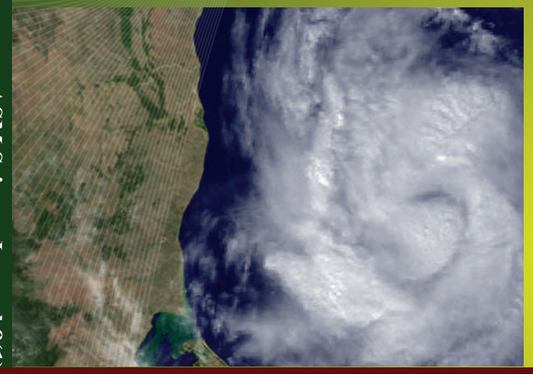

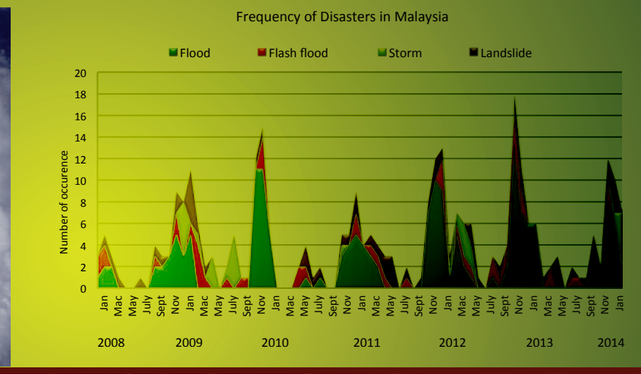

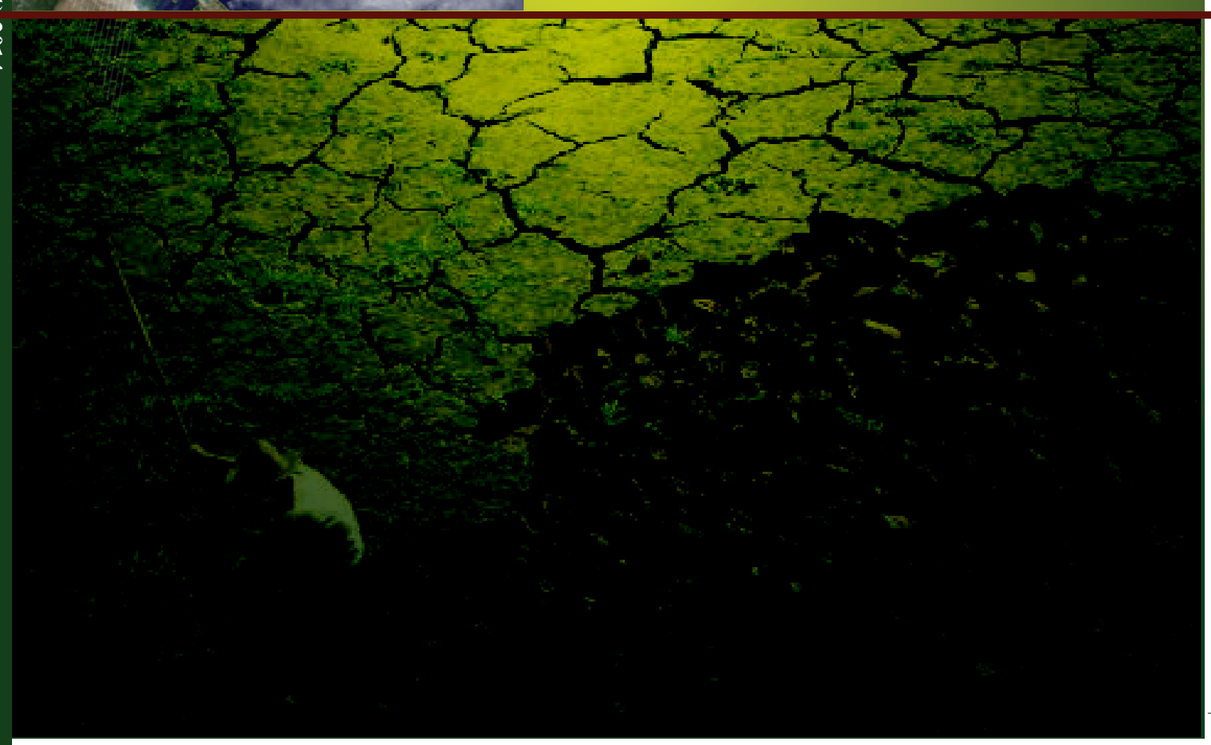

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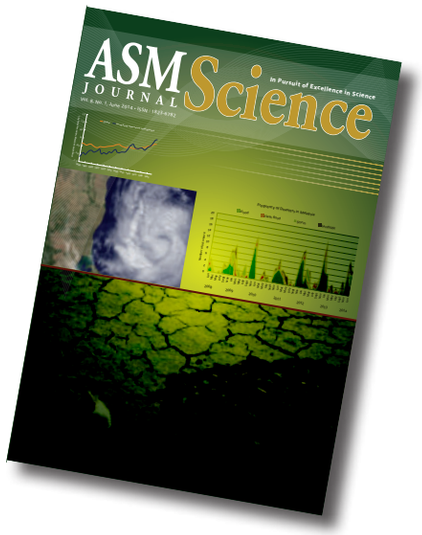
ASM Science
JOURNAL

Cover:

The cover design was dictated by topical themes in research and in the media related to 'climate change', 'El Nino', disasters related to climate extremes, and the article contributions to this issue of the Journal (pp. 1–10; 67–69; and 83–85).

In an article (pp. 1–10) entitled *Science and Technology for Disaster Prevention and Climate Resilience in Asia*, scientists from Universiti Kebangsaan Malaysia (UKM), Cambridge/University College London and City University, Hong Kong highlight current advances in climate modelling, weather forecasts, hazards and the potential for land-based mitigation-adaptation strategies. The picture in the lower-half of the cover [from the Intergovernmental Panel on Climate Change *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* in 2012 (Source: Julian Hunt, presentation at the *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia)] depicts an extreme dry weather condition and its combined consequences—farming and human activity for sustenance. The NASA satellite image, in the centre of the cover, is that of cyclone Thane's predicted accurate tracks (on 28 December 2011 in south-eastern India)—an example of science and technology (S&T) in weather forecasting—but warnings could have reduced the damage to life, property, infrastructure, etc. if there were closer co-operation/collaboration/communication/governance among meteorological stations, emergency responders and end-user communities!

The frequency chart in the centre of the cover exemplify major media reports on the occurrence of flash floods, floods, landslides and storms in Malaysia (data from Southeast Asia Disaster Prevention Research Initiative, UKM); this together with the line graph on the top-left corner was extracted from a commentary, by researchers from UKM and Cambridge/University College London, entitled *Climate Science and Technology for Disaster Prevention* (pp. 83–85) which reason insights on S&T needs for coping with new challenges of risk management and climate adaptation for the extended mega urban region. The data, for the line graph was garnered by the Hong Kong Observatory Headquarters, give support to the fact that the annual mean temperature anomaly of Hong Kong is higher than the global level since the 1990s—attesting the urgency to address the downstream impacts of the urban heat island effect.



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The Academy of Sciences Malaysia (ASM)

The Academy of Sciences Malaysia (ASM) was established, under the *Academy of Sciences Act 1994* which came into force on 1 February 1995, with the ultimate aim to pursue excellence in science. Thus the mission enshrined is to pursue, encourage and enhance excellence in the field of science, engineering and technology for the development of the nation and the benefit of mankind.

The functions of the Academy are as follows:

- To promote and foster the development of science, engineering and technology
- To provide a forum for the interchange of ideas among scientists, engineers and technologists
- To promote national awareness, understanding and appreciation of the role of science, engineering and technology in human progress
- To promote creativity among scientists, engineers and technologists
- To promote national self-reliance in the field of science, engineering and technology
- To act as a forum for maintaining awareness on the part of the Government of the significance of the role of science, engineering and technology in the development process of the nation and for bringing national development needs to the attention of the scientists, engineers and technologists
- To analyse particular national problems and identify where science, engineering and technology can contribute to their solution and accordingly to make recommendations to the Government
- To keep in touch with developments in science, engineering and technology and identify those developments which are relevant to national needs to bring such developments to the attention of the Government
- To prepare reports, papers or other documents relating to the national science, engineering and technology policy and make the necessary recommendations to the Government
- To initiate and sponsor multi-disciplinary studies related to and necessary for the better understanding of the social and economic implications of science, engineering and technology
- To encourage research and development and education and training of the appropriate scientific, engineering and technical man power
- To establish and maintain relations between the Academy and overseas bodies having the same or almost similar objectives in science, engineering and technology as the Academy
- To advise on matters related to science, engineering and technology as may be requested by the Government from time to time; and
- To carry out such other actions that are consistent with the *1994 Academy of Sciences Act* as may be required in order to facilitate the advancement of science, engineering and technology in Malaysia, and the well being and status of the Academy.

The Academy is governed by a Council. Various Working Committees and Task Forces are charged with developing strategies, plans and programmes in line with the Academy's objectives and functions.

The functions of the Council are:

- To formulate policy relating to the functions of the Academy
- To administer the affairs of the Academy
- To appoint such officers or servants of the Academy as are necessary for the due administration of the Academy
- To supervise and control its officers and servants
- To administer the Fund; and
- To convene general meetings of the Academy to decide on matters which under this Act are required to be decided by the Academy.

The Academy has Fellows and Honorary Fellows. The Fellows comprise Foundation Fellows and Elected Fellows. The Academy Fellows are selected from the ranks of eminent Malaysian scientists, engineers and technocrats in the fields of medical sciences, engineering sciences, biological sciences, mathematical and physical sciences, chemical sciences, information technology and science and technology development and industry.

The Future

Creativity and innovation are recognised the world over as the key measure of the competitiveness of a nation. Within the context of K-Economy and the framework of National Innovation System (NIS), ASM will continue to spearhead efforts that will take innovation and creativity to new heights in the fields of sciences, engineering and technology and work towards making Malaysia an intellectual force to be reckoned with.

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Science and Technology for Disaster Prevention and Climate Resilience in Asia

J.J. Pereira[1]*, J.C.R. Hunt[2] and J.C.L. Chan[3]

The role of science and technology (S&T) in preventing disasters and building resilience to climate change is featured in this paper, drawing primarily on the presentations and discussion of researchers, practitioners and policy makers from 31 institutions in 17 countries during the *Workshop on Natural Disasters and Climate Change in Asia*, held on 5–7 November 2012 in Bangi, Malaysia. Issues highlighted include advances in climate modelling and weather forecasts, with emphasis on information gaps; hazards and its cascading effects, focusing on current research and approaches; and the potential for land-based mitigation-adaptation strategies. Progress in mobilizing S&T to support disaster prevention and climate resilience is hindered by factors such as absence or lack of research, incomplete and non-existent scientific records, restricted access to data and capacity to innovate and transmit S&T, among others. The establishment of an Asian Network for Climate Science and Technology is proposed to provide and facilitate exchange of information and aid development of research co-ordination projects led by Asian researchers and possibly to act as a one-stop repository of global climate change related research too. The scope of the network would cover climate research with particular relevance to disaster resilience, including scientific capacity, which is all very distinct in Asia.

Key words: Science and technology; climate research; Asian climate change adaption; climate mitigation; climate change; policy; institutions; Workshop; climate modelling; weather forecasts; hazards; strategies; disaster prevention; Asian Network; Asian researchers

In early 2012, the Intergovernmental Panel on Climate Change (IPCC) issued the Special Report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)* (Figure 1). The report is an integrated perspective of three historically distinct groups of scientists. These are specialists in disaster recovery, disaster risk management and disaster risk reduction, who are mostly new to the IPCC; authorities in the areas of the physical science basis of climate change, who are generally associated with Working Group 1 of the IPCC; and experts in climate change impacts, adaptation, and vulnerability, who work under the auspices of Working Group 2 of the IPCC. Past IPCC assessments have focused primarily on extreme weather and climate events. Extreme weather and climate events contribute physically to risk of disasters, and in combination with human influence, the consequences can be severe. The past few years have seen advancement in the science of such events, their impacts and options for solutions. This has enabled the IPCC to conduct an assessment of scientific, technical and socio-economic knowledge within peer reviewed literature as of May 2011.

Disasters as defined in the IPCC-SREX refers to "severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" (IPCC 2012, p. 31). The hazardous physical events that cause disasters may be natural, human induced or a combination thereof. In many cases, extreme events are associated with disasters. However, depending on the physical and social conditions, non-extreme physical events, such as steady sea level rise can also lead to disasters, and this is reflected in most disaster databases (IPCC 2012). The IPCC-SREX focuses on the relationship between climate change and extreme weather and climate events, and also the impacts of these events on vulnerable societies. The challenge of dealing with extreme weather and climate events is framed as an issue in decision-making under uncertainty. Aspects covered include risk management; observed and projected changes in extreme weather and climate events; as well

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as exposure, vulnerability and losses resulting from such events. Adaptation options are also presented, from local to international scales. The implications for sustainable development are also emphasized.

The IPCC-SREX served as the basis to bring together researchers, practitioners and policy makers, representing the three historically distinct communities working on disaster issues, climate science and climate adaptation in Asia, to consider future needs for the region. This was the context for the *Workshop on Natural Disasters and Climate Change in Asia*, which was successfully held from 5–7 November 2012 at Hotel Equatorial, Bangi, Malaysia. The Workshop was also a follow-up to another regional meeting held in India the year before, which made a strong call for researchers in Asia to interact with each other and advance science and technology pertaining to climate change (Srinivasan & Hunt 2011).

The *Workshop on Natural Disasters and Climate Change in Asia* was jointly organized by the Southeast Asia Disaster Prevention Research Institute of Universiti Kebangsaan Malaysia (SEADPRI-UKM), the Cambridge Malaysian Education and Development Trust in Association with the Malaysian Commonwealth Studies Centre at the University of Cambridge, National Security Council of the Prime Minister's Department and the Ministry of Natural Resources and Environment. The collaborating institutions were the Advisory Committee on Protection of the Sea; City University of Hong Kong; Divecha Centre for Climate Change, Indian Institute of Science; UKM's Research Centre for Tropical Climate Change System and Institute of Climate Change; Asian University Network for Environment and Disaster Management (AUEDM); Asia Pacific Adaptation Network (APAN); and Asia Pacific Network for Global Change Research (APN). About a hundred participants from 31 institutions in 17 countries

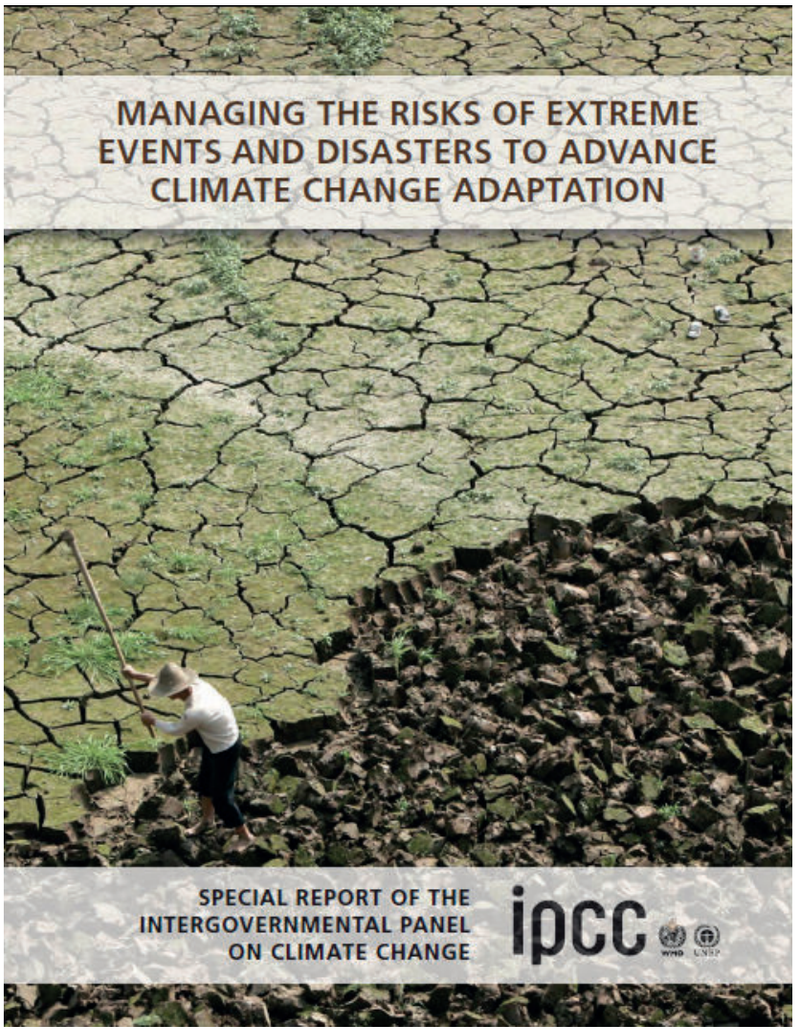

Figure 1. The Intergovernmental Panel on Climate Change released the *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)* in 2012. Extreme weather and climate events contribute physically to risk of disasters, and in combination with human influence, the consequences can be severe.

attended the three-day Workshop. An IPCC-SREX Keynote Address was delivered by Co-ordinating Lead Author Dr Padma N. Lal of Australia and this was followed by the presentation of a total of 30 invited technical papers.

This paper draws mainly on the presentation and discussion of researchers, practitioners and policy makers at the Workshop to feature the role of science and technology (S&T) in preventing disasters and building resilience to climate change in Asia. It commences with a brief account of advances in climate modelling and weather forecasts, with emphasis on information gaps. This is followed by a discussion on hazards and its cascading effects, focusing on current research and approaches. Subsequently, climate change mitigation and advances that may be applicable to the region is highlighted. A short discourse on challenges related to mobilizing S&T in Asia precedes the concluding remarks.

Climate Modelling and Weather Forecasts

Asia has complex and special geographical characteristics, which influence regional and local atmospheric and oceanographic phenomena and their interactions with the global climate. As in climate systems generally, it is also necessary to consider multi-scale interactions and chaotic pattern changes from the meso-scale to planetary scale motions. Research indicates that heavier rain associated with typhoons should be expected with climate change and at landfall such heavy rain will lead to more disasters associated with flooding (Chan 2012). Flooding is likely to be exacerbated since storm surge will be higher due to sea-level rise. Other extreme and damaging phenomena are associated with longer periods of heat, drought and rain among others, which several major computer models are now indicating as being more likely in future. S&T support is necessary to deal with the new challenges of risk management and climate adaptation in these changing conditions.

In Korea, a climate projections databank, the CORDEX-East Asia domain (50 km horizontal resolution) is currently produced by the National Institute of Meteorological Research, Korea Meteorological Administration and three universities in Korea i.e. Seoul National University, Yonsei University and Kongju National University (Cho *et al*. 2012). The Coordinated Regional Climate Downscaling Experiment (CORDEX) is supported by the World Climate Research Program to organize an international co-ordinated framework to produce regional climate change projections drawing on research communities over the world for climate change impact and adaptation studies. A major aim of the CORDEX initiative is to provide co-ordinated model evaluation and a climate projection framework, and an interface to the applicants of the climate simulations in climate change impact, adaptation, and mitigation studies. There are eleven CORDEX domains over the world, covering most of Asia, the western Pacific, Bay of Bengal, and the South China Sea. Of these, CORDEX-East Asia is the biggest and it is designed as a user-friendly web portal.

In Japan, the Earth Simulator Center is developing the Multi-scale Simulator for the Geoenvironment (MSSG), an ultra-high resolution coupled model that incorporates non-hydrostatic atmosphere, ocean, land and sea-ice model components, which is made tailored to high performance computing architectures (Takahashi *et al.* 2012). The MSSG is a coupled model with a nesting scheme between the globe and a region, capable of conducting seamless, comprehensive simulations with a single model for different scales ranging from the entire globe to urban areas. Research is now focused on understanding the relationship between heat island phenomena and increasing heavy rain in Tokyo, using simulations with ultra-high resolution MSSG. The goal is to provide insights on adaptation scenarios for the urban environment.

A regional forecast system has been developed for South Asia based on a regional model that can explicitly represent atmospheric convection and also provides a much improved representation of topographical influences on the local weather (Gordon 2012). The system, which was developed by the UK Met Office (4 km or 1.5 km resolution), yields forecasts that provide greater detail of parameters such as heavy rainfall amounts or maximum wind speeds that are important in severe weather. The fully operational forecast system is designed to be easily relocated to any geographical region.

Southeast Asia is host to the Severe Weather Forecast Demonstration Project (SWFDP) established by the World Meteorological Organisation (Gordon 2012). The main goals of the SWFDP are to improve severe weather forecasting, to improve the lead-time of warnings and to improve the interaction of National Meteorological and Hydrological Services with media, disaster management and civil protection authorities. Where the provision of forecasts is concerned, the global producing centres, which run the state-of-the-art global forecast systems, make their forecasts available to the region. The models used in the global forecasting systems typically have a resolution of 20 km – 50 km. These model forecasts are provided within the SWFDP via web portals along with guidance and interpretation provided by a specialist centre within the region.

Generally, better understanding is needed of how major modes of climate variability such as El Nino-Southern Oscillation, Indian Ocean Dipole and Madden-Julian Oscillation would be affected by anthropogenic warming and thus impact Southeast Asia, compared to East and South Asia. The current grasp is poor partly due to the inability of most climate models to simulate these phenomena for Southeast Asia, particularly Malaysia

(Tanggang 2012). Recent developments in the S&T of weather forecasting systems can now be applied in Southeast Asia to substantially enhance severe weather early warnings (Arribas 2012). Successful deployment into early warning systems requires research partnerships and enhanced capacity of National Meteorological Services, emergency responders and end-user communities (Figure 2).

Hazards and their Cascading Effects

Many countries in Southeast Asia are particularly vulnerable to climate-related hazards, such as floods, landslides, droughts and typhoons (Marley-Zagar 2012; Lwin 2012; Eko 2012). Coastal and low-lying areas in the region are also threatened by sea-level rise and storm surges, which cause coastal erosion (Pak 2012). Geological hazards such as landslides and subsidence, as well as technological hazards and environmental degradation are also influenced by climate variability and change depending on the circumstances (Pereira *et al*. 2012). Some areas may experience landslides, mudflows or slope failures, depending on the combination of extreme rainfall, saturated soil conditions and other factors. Others may experience flash floods, and environmental contamination may result where floodwaters overwhelm sewerage, waste disposal sites and other sources of pollution. The Fukushima nuclear disaster is an example of how a geological hazard (earthquake) can have a cascading effect to cause a technological disaster.

Research on the potential for such cascading hazards requires detailed knowledge of surface and subsurface conditions of the local area, in addition to potential factors that are influenced by changing climatic conditions. Such studies are commencing in Malaysia where all available information on the history of disasters and local geology is being utilised to develop a holistic and integrated approach for disaster prevention (Pereira *et al*. 2012). Delineation of areas that are highly susceptible to hazards and cascading hazards in the wake of climate change and variability should be given priority in the adaptation strategy of a country (Figure 3). Identification of vulnerable communities and their involvement in developing disaster risk reduction plans that also enhance climate resilience at the local level should also be emphasised.

In the Philippines, the Department of Science and Technology has launched the Nationwide Operational Assessment of Hazards programme to provide early warning to vulnerable communities through the use of advanced technology that enhances current landslide and flood vulnerability mapping (Lagmay 2012). The mission is to undertake disaster science research and development; advance the use of cutting-edge technologies; and recommend innovative information services for government funded disaster prevention and mitigation efforts. The use of S&T is complemented with the application of a bottom-up disaster prevention approach involving all stakeholders including academics to create resilient communities. For example, during the course of a flood event individuals provide informal information to expert centres on aspects such as the level of water in the street in relation to people's bodies (ankles, knees, chest etc.), and the direction and strength of water currents, obstructions caused by collapsing buildings, floating trees and vehicles, among others (Figure 4).

This is very useful, since even the best urban flood models and monitoring programmes require updated information to improve short-term prediction of flooding over urban and rural areas. The information is then interpreted so as to provide simple messages to communities — e.g. either to wait because the flood is receding or to evacuate because it is becoming more dangerous. This shows why investment in resilient communication networks, mobile phones and on-line operational centres is essential for protecting communities, especially those subject to repeated natural disasters.

Flooding in Thailand has been subject to many studies from various disciplines. Hydrological studies on the causes of flooding have contributed to the identification of short- and long-term flood prevention measures including dam operations protocols to prevent future flooding (Koontanakulvong 2012). The Strategic Committees and working teams that have been established by the Government of Thailand are now considering the measures for implementation.

In dealing with climate change, the Sikep Samin Communities of Indonesia believe that land should be valued, respected and venerated and that it is critical to preserve the balance of nature where over exploitation would lead to calamities such as floods and landslides (Eko 2012). The Sikep Samin Community is now trying to return to organic farming methods without chemical fertilizers and pesticides. Liquid fertilizer is made from natural products such as coconut water, water used to wash rice (Leri), Moringa leaves and banana stems that are fermented with molasses for about a month. The Community also draws on spring water from the Kars Region G. Kendeng to meet their irrigation needs. The Sikep Samin community has been found to be more adaptable to change in climate compared to other farming communities.

Many small glaciers located in low altitude range of the Indian Himalaya are losing mass at substantial rates and this could significantly influence their function as sources of water (Kulkarni 2012). There are major international programmes to study and understand the changing dynamics of Himalayan glaciers and its impacts on local communities. This is particularly relevant not only in the context of water availability but also with respect to

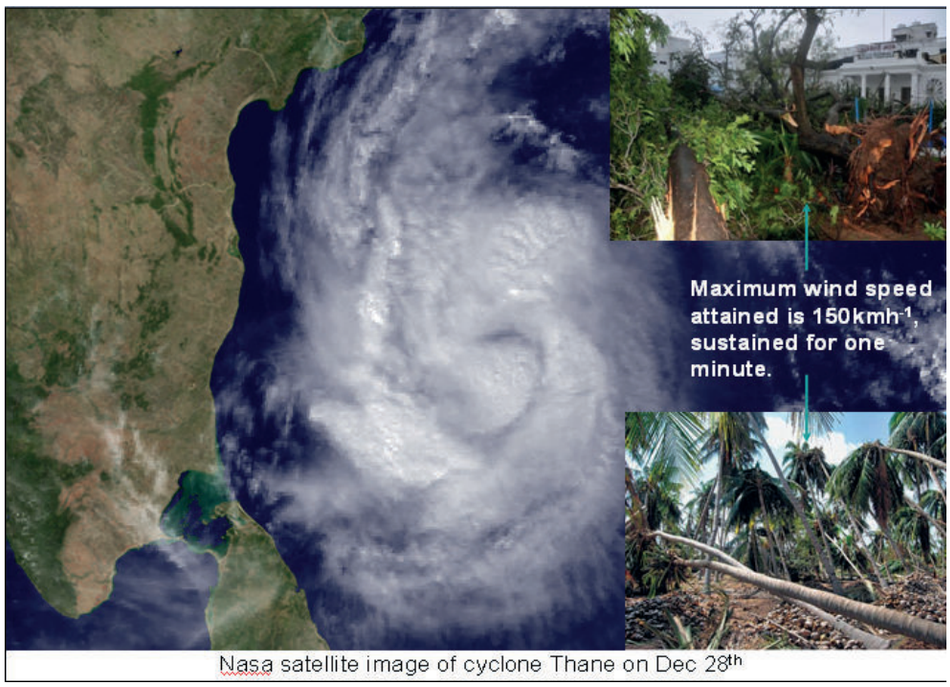

Figure 2. The NASA satellite image of Cyclone Thane on 28 December 2011 in India — the predicted tracks were accurate but warnings could have been further improved through enhanced partnership between the National Meteorological Service, emergency responders and end-user communities (Source: Julian Hunt, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

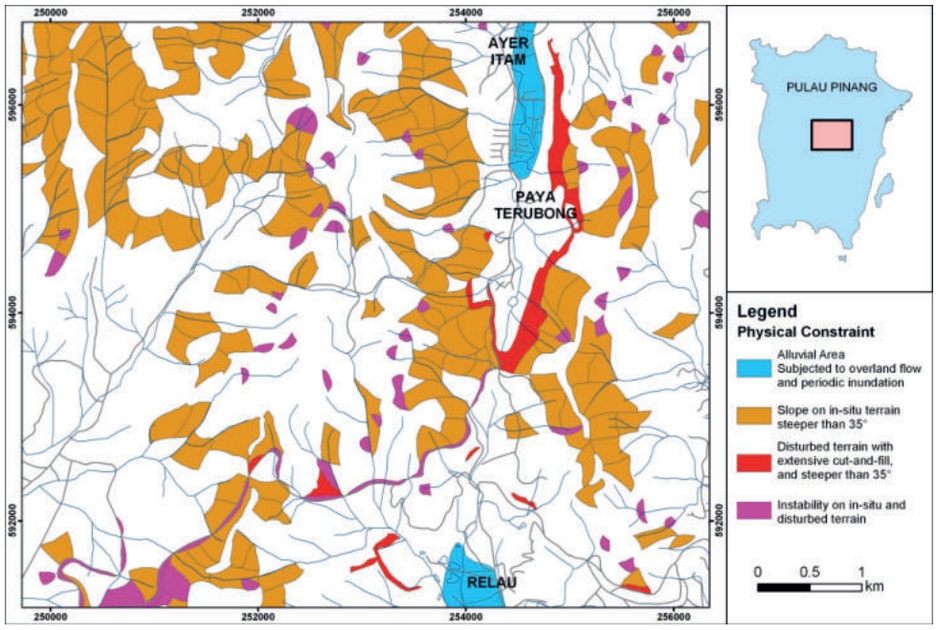

Figure 3. Terrain mapping conducted by the Minerals and Geoscience Department of Malaysia delineates areas that are susceptible to landslides and floods. Geological information serves as the basis to identify the potential for cascading hazards due to climate variability and change (Source: T.F. Ng, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

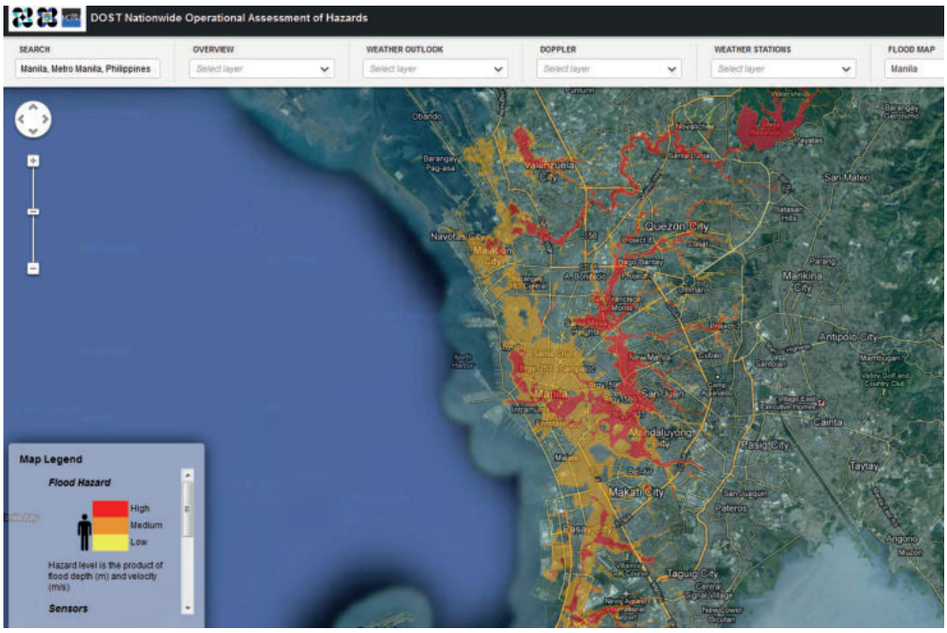

Figure 4. Nationwide Operational Assessment of Hazards — science and technology is complemented with information from stakeholders via the social media. During the course of a flood event in Manila, individuals provide informal information to expert centres (Source: A.M.F.A. Lagmay, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

flooding, riverbank erosion and other cascading hazards that downstream riverbank communities may be exposed to.

Modelling also has a role to play in supporting informed decision-making with respect to hazards. Digital Elevation Models with enhanced LIDAR WIKI technology can be used in the GIS platform to create detailed 2D flooding simulations (Stelling 2012). Off-line models can support water management in terms of design, planning and control of urban and rural areas.

Precipitation in southern India is being artificially augmented cloud seeding using calcium chloride at altitudes between 1200 to 2500 metres above the mean sea level (Ghosh 2012). This process at best is about 20% certain; too expensive for developing countries. It is also controversial given its trans-boundary effects and lack of international protocols (Hunt & Pereira 2012). Seeding operations are likely to be more effective if they are planned with the aid of aerosol-cloud microphysical modelling studies. In particular this would enable the most suitable aerosol size distributions to be used (Ghosh 2012).

Natural changes in combination with human influences can result in increased tsunami inundation if the flow resistance of the bottom surface is decreased, e.g. by removing coral reefs or mangrove swamps. Also the more rapid sea level rise in equatorial regions will increase the impacts of tsunamis on coastal communities (Klettner 2012). High resolution 2D numerical simulations of the Navier-Stokes equation are found to be useful to model the momentum and energy of waves as a tsunami propagates in typical near shore topography over various geometries (Klettner 2012). Research is progressing to improve the model to delineate tsunami inundation in a changing climate. Geological, archaeological and historical evidence as well as indigenous knowledge can provide inputs to determine the frequency of past tropical cyclone events in coastal areas (Switzer 2012). Integrated research that incorporates geological analysis of long-term recurrence intervals with shorter records from historical archives, archaeology and indigenous knowledge is contributing to better infrastructure design, risk analysis and insurance pricing.

Mitigation and Climate Resilience

Global consumption of energy due to fossil fuel combustion has quadrupled over the last fifty years. Anthropogenic emissions of 34 Gt/yr have increased atmospheric greenhouse gases, particularly carbon dioxide from 315 to 385 parts per million from 1960 to 2012, and contributed to an increase in average global temperature by about 1ºC (Huppert 2012). The storage of carbon dioxide by pumping liquid or supercritical carbon dioxide into porous

reservoir rocks, such as depleted oil and gas fields and regional saline aquifers, is a measure to restore balance and mitigate climate change. In the Sleipner natural gas field of Norway, carbon dioxide has been injected at the rate of about 1 Mt/yr since 1996 (Huppert 2012). The rate and form of carbon dioxide propagation can be improved by building on theoretical and experimental investigations of input of liquid of one viscosity and density from a point source above an impermeable boundary, either horizontal or slanted, into a porous medium saturated with liquid of different viscosity and density. Such investigations could be tested in Asia, to improve carbon dioxide injection rates for sequestration, taking into account cost factors.

Mitigation measures can extend beyond technological measures to reduce greenhouse gases to encompass integrated mitigation-adaptation strategies (Hunt 2009) although such strategies would depend on urbanization pathways and emissions scenarios. This is well illustrated by the studies in the Sun Corridor, which comprises the rapidly expanding metropolitan areas of Phoenix, Tucson, Prescott and Nogales in Arizona, United States. Scenario-based projections of the Sun Corridor growth through 2050, was coupled to an urban canopy model, to explore direct climate consequences of rapidly urbanizing megapolitan complexes (Georgescu 2012). Models based on a high Sun Corridor expansion scenario indicate that local summertime warming approaches 4ºC, with urbanizing regions primarily experiencing a 3ºC – 4ºC increase in near-surface temperature. The models indicate that the incorporation of 'cool' — e.g. vegetated irrigated-roofs would reduce this warming by about half, meeting the needs of both mitigation and adaptation. This has also been demonstrated in a number of Asian cities, notably New Delhi. The assessment of urban impacts should be expanded beyond a mere focus on mean temperature to include consequences for the entire climate system including the regional hydrologic cycle (Georgescu 2012).

Mobilizing Science and Technology

Advances in science and technology, drawing on more accurate observations, computations and communication, has led to improving the reliability and practical relevance of short- term and on-going warnings, which are highly effective in reducing the impacts of tropical typhoons, rainstorms, floods and other hazards (Hunt & Pereira 2012). However, in many countries of Asia, there are challenges in capitalising on such advances to benefit vulnerable communities. The importance of communication and education as well as the availability of low-cost technologies are vital.

Availability and access to data is critical for effective use of technology and infrastructure to benefit industry and communities that are exposed to hazards. Data sets on weather-related natural disasters and regional climate change and their social and economic consequences are limited in Asia, particularly in Southeast Asia. This shortcoming is compounded by limited access to scientific data in many sub-regions, particularly at the national level. In some countries, such as Italy, background data on the atmosphere and bodies of water is freely available to the public. This data is then used to provide personalised exposure information, which is then used by local communities and government to take preventive action.

Incomplete and non-existent scientific records pose uncertainties in the prediction of hazards. Sparse and/or incomplete existing records provide some estimates of the general nature and likelihood of occurrence of these hazards, but are usually of limited use for modelling and accurate prediction. In many places, methods are employed from geological, archaeological, social and historical studies to provide longer records and provide valuable insights into past impacts. However, the application of such methods is limited in the Asian region. The lack of understanding and knowledge gaps in various disciplines related to disaster and climate change research is disquieting.

Greater capacity to innovate and transmit S&T would enhance disaster and climate resilience in many parts of Asia. This is particularly relevant for Southeast Asia, where the Association of Southeast Asian Nations is initiating its first ever collaborative initiative to build capacity on climate change adaptation for disaster prevention. Institutional planning and co-ordination for development of multidisciplinary research programmes on disaster and climate resilience is needed at regional and national levels. Establishing strong networking among researchers and academics is critical for building capacity in multidisciplinary and integrated approaches that address natural disasters and climate change. This should be complemented with multi-stakeholder participation at the local level to enhance disaster and climate resilience (Pereira *et al*. 2009).

Scientists need to contribute to the provision of advisory services to governments and communities, even where there may be some disagreements between them. Ultimately governments and communities have to decide on which precautions to take before and during various hazards. They will be more confident if there is open discussion among scientists, who are informed by social experiences of disasters and the relevant controversies, as in the case of hazard prediction preceding and during earthquakes and volcano eruptions. The growing belief that the atmosphere and oceans should be deliberately engineered (geo-engineering) to combat climate change and its effects is another contentious issue that requires open and informed dialogue.

There are several networks on climate change and disaster risk reduction operating in Asia. These include the AUEDM, APAN and APN. However, these networks involve multi-stakeholders primarily policy and decision makers, practitioners, non-government organisations as well as researchers. There is no network that is dedicated solely to building capacity on disaster and climate resilience research, which is underpinned by socialised S&T. Such a network could bring together researchers from various disciplines to a multidisciplinary platform to build their capacity while simultaneously interacting with other multi-stakeholder networks, intergovernmental bodies and multi-lateral institutions operating in the region.

Given this scenario, it was agreed that the Asian Network of Climate Science and Technology will be established, involving a core group of institutions from Asia, where SEADPRI-UKM would take the lead with initial support from the Malaysian Commonwealth Studies Centre of Cambridge University. The Network will operate virtually (i.e. through websites) to provide information and develop research co-ordination projects led by Asian researchers, focussing on particular aspects of climate and disaster resilience specific to Asian conditions and phenomena. The scope of the network would cover climate projection and disaster resilience including scientific capacity, which is all very distinct in Asia. The proposed new network differs from existing ones through a focus on scientific aspects, while retaining disaster applications motivation. However there would be strong co-ordination with existing and planned networks involved in other areas of science and technology. A key activity will be to establish a web-based directory of researchers, their institutions, programmes and publications, which will be cross-referenced according to subject and area in Asia. Convenors of special topic groups will be identified and where possible these groups should make use of international and regional funding for meetings and activities; or have side meetings at international events. As the network expands and sustains itself, national co-ordinators could be appointed and funded in their own countries; similar to the European Research Community for Flow Turbulence and Combustion (ERCOFTAC).

CONCLUDING REMARKS

First of all strengthening S&T in Asia is essential both for applications and public understanding. This is the basis for improved disaster prevention and climate resilience to deal with hazards that prevalent in the region and rapidly growing populations that are vulnerable. Coasts, floodplains and unstable mountain slopes and deserts are among the regions exposed to hazards associated with climate variability and change. There has been considerable progress in S&T in dealing with some aspects of hazards, notably in climate modelling, weather forecasts as well as prediction of flood and coastal inundation, among others. Advances in climate change mitigation, particularly land-based mitigation-adaptation strategies are relevant to Asia.

Notwithstanding this, there are many issues that hinder progress in mobilizing S&T to support disaster prevention and climate resilience in the region. A particular problem is incomplete and non-existent scientific records, and restricted access to data. Many universities and government agencies in developing countries have centres of Information and Communication Technology and Geographical Information System, which are now being used to grow capacity and transmit S&T. Openness among scientists and scientific organisations (especially in relation to data being freely available as in the Italian model) as well as incorporation of all perspectives, particularly that of local communities and other stakeholders should play a greater role in disaster prevention and climate resilience.

The establishment of Asian Network for Climate Science and Technology (ANCST) is proposed to provide and to facilitate exchange of information and to aid development of research co-ordination projects led by Asian researchers, focussing on particular aspects of climate change and variability and of disaster resilience that are specific to the region. ANCST could possibly serve as a one-stop repository of global climate change related research too. The scope of the network would cover climate research with particular relevance to disaster resilience, including scientific capacity, which is all very distinct in Asia. There would be strong co-ordination with existing and planned networks involved in other areas of science and technology.

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Evaluation of the Effect of Radio Frequency Interference on Global Positioning System (GPS) Receivers via GPS Simulation

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In this study, Global Positioning System (GPS) simulation was employed to study the effect of radio frequency interference (RFI) on two hand-held GPS receivers; Garmin GPSmap 60CSx (evaluated GPS receiver) and Garmin GPSmap 60CS (reference GPS receiver). Both GPS receivers employed the GPS L1 coarse acquisition (C/A) signal. It was observed that the interference signal power levels required to affect the location fixes of the GPS receivers were significantly high compared to the corresponding GPS signal power levels. The noise-like C/A code structure, which modulated the L1 signal over a 2 MHz bandwidth, allowed for the signal to be received at low levels of interferences. The evaluated GPS receiver had better RFI operability as compared to the reference GPS receiver. This is because the evaluated GPS receiver had higher receiver sensitivity, allowing it to have increased carrier-to-noise density (C/N0) levels for GPS satellites tracked by the receiver. The absence of other error parameters, including ionospheric and tropospheric delays, satellite clock, ephemeris and multipath errors, and unintentional signal interferences and obstructions, resulted in the required minimum jamming power levels in this study to be significantly higher as compared to field evaluations. These minimum jamming power levels vary with location and time. This was due to the GPS satellite constellation being dynamic, causing varying GPS satellite geometry over location and time, resulting in the minimum required GPS jamming power levels being location / time dependent. In general, the lowest minimum jamming power levels were observed for readings with the highest position dilution of precision (PDOP) values, and vice versa.

Key words: Global Positioning System; simulation; radio frequency interference; position dilution of precision; GPS L1 coarse acquisition signal; carrier-to noise-density (C/N_0)

There is a steady growth in the entrenchment of Global Navigation Satellite Systems (GNSS) in current and upcoming markets, having penetrated various consumer products, such as cell phones, personal navigation devices (PNDs), cameras and assimilation with radio-frequency identification (RFID) tags, for various applications, including navigation, surveying, timing reference and location based services (LBS). While the Global Positioning System (GPS), operated by the US Air Force (USAF), is the primarily used GNSS system worldwide, the upcoming Galileo and Compass systems, and the imminent conversion of *Global'naya Navigatsionnaya Sputnikovaya Sistema* (GLONASS) signals from frequency division multiple access (FDMA) to code division multiple access (CDMA) look set to make multi-satellite GNSS configurations the positioning, navigation and timing (PNT) standard for the future.

However, many GNSS users are still not fully aware of the vulnerabilities of GNSS systems to various error parameters, such as ionospheric and tropospheric delays, satellite clock, ephemeris and multipath errors, satellite positioning and geometry, and signal interferences and obstructions. These error parameters can severely affect the accuracy of GNSS readings, and in a number of cases, disrupt GNSS signals (Volpe 2001; Kaplan & Hegarty 2006; Dinesh 2009, 2011; Last 2010; Schwartz 2010; RAE 2011; Schue 2012).

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One particular vulnerability that has received significant attention is jamming. Jamming is defined as the broadcasting of a strong signal that overrides or obscures the signal being jammed (DOA 2009; JCS 2007; Poisel 2002). Since GNSS satellites, powered by photocells, are approximately 20 200 km above the Earth surface, GNSS signals that reach the Earth have very low power levels (approximately –160 dBm to –130 dBm), rendering them highly susceptible to jamming (Adams 2001; Johnston & Warner 2004; Papadimitratos & Jovanovic 2008; Last 2010; Schwartz 2010; Jones 2011; Grant *et al*. 2011; Pullen & Gao, 2012). For example, a simple 1 W battery-powered jammer can block the reception of GNSS signals approximately within a radius of 35 km from the jammer (Papadimitratos & Jovanovic 2008).

Given the various incidents of intentional and unintentional jamming of GNSS signals, including military GNSS signals (Adams 2001; Williams 2006; Jewell 2007; Last *et al*. 2010; Chosunilbo 2011), the development of various GNSS anti-jamming technologies has received significant attention (Casabona & Rosen 1999; Gustafon *et al*. 2000; Deshpande 2004; Loegering 2006; Meng *et al*. 2008; Zhuang *et al*. 2009; Wilde & Willems 2010; Murfin 2011; Jones 2011; Cuntz *et al*. 2012; Hunkeler *et al*. 2012; Chen *et al*. 2013). In addition, many current GNSS receiver evaluations concentrate on radio frequency interference (RFI) operability (FAA 1996; ION 1997; Rash 1997; Gautier 2003; Agilent 2008; Weinstein *et al*. 2009; Boulton *et al*. 2011). A number studies have also been conducted to evaluate the effect of RFI on GPS signals, using both field evalutions (Deshpande 2004; Mitch *et al*. 2011; Baek *et al*. 2012; Ahmad Norhisyam *et al*. 2013) and GNSS simulations (de Bakker 2007; Ko 2013; Dixon *et al*. 2013).

The Science and Technology Research Institute for Defence (STRIDE) conducted a series of tests to study the effect of RFI on the GPS L1 coarse acquisition (C/A) signal (Dinesh *et al*. 2009a, 2010a, b). All the tests conducted were via field evaluations using live GPS signals. However, such field evaluations are subject to various error parameters which are uncontrollable by users.

The ideal GPS receiver evaluation methodology would be using a GPS simulator, which can be used to generate multi-satellite GPS configurations, transmit GPS signals which simulate real world scenarios, and adjust the various error parameters. This would allow for the evaluations of GPS receiver performance under various repeatable conditions, as defined by users. As the evaluations are conducted in controlled laboratory environments, they will not be inhibited by unwanted signal interferences and obstructions (Aloi *et al*. 2007; Dinesh *et al*. 2009b; Petrovski *et al*. 2010; Kou & Zhang 2011).

In this study, GPS simulation is employed to study the effect of RFI on two handheld GPS receivers; Garmin GPSmap 60CSx (Garmin 2007) (evaluated GPS receiver) and Garmin GPSmap 60CS (Garmin 2004) (reference GPS receiver). Both GPS receivers employ the GPS L1 C/A signal. The use of different GPS receivers is to compare how varying receiver sensitivities (higher for the evaluated receiver and lower for the reference receiver) affect RFI operability. The focus of this study is on the minimum required interference signal power levels required to jam the respective GPS receivers. Furthermore, it is demonstrated that these minimum jamming power levels correlate with GPS coverages at the simulated locations and times used in the study.

METHODOLOGY

The apparatus used in the study were an Aeroflex GPSG-1000 GPS simulator (Aeroflex 2010), an Advantest U3751 spectrum analyser (Advantest 2009), an IFR 2023B signal generator (IFR 1999), a Hyperlog 60180 directional antenna (Aaronia 2009), and a notebook running GPS Diagnostics v1.05 (CNET 2004). The study was conducted in the STRIDE semi-anechoic chamber (Ghafar *et al*. 2010) to avoid external interferences signals and multipath errors. The test setup employed is as shown in Figure 1. Simulated GPS signals were generated using the GPS simulator and transmitted via the coupler, while interference signals were generated using the signal generator and transmitted via the directional antenna. The following assumptions were made for the tests conducted:

- No ionospheric or troposheric delays
- Zero clock and ephemeris error
- No multipath fading or unintended obstructions; and
- No unintended interference signals.

The date of simulation was set at 10 January 2012. The almanac data for the period was downloaded from the US Coast Guard's web site (USCG 2011), and imported into the GPS simulator. For each GPS receiver, the test procedure was conducted for GPS signal power levels of –131 dBm to –156 dBm (decrements of 5 dBm), and co-ordinated universal time (UTC) times of 0000, 0300, 0600 and 0900 for the following co-ordinates:

- N 2° 58’ E 101° 48’ (Kajang, Selangor, Malaysia)
- N 39° 45’ W 105° 00’ (Denver, Colorado, USA)
- S 16° 55’ E 145° 46’ (Cairns, Queensland, Australia)
- S 51° 37’ W 69° 12’ (Rio Gallegos, Argentina).

Trimble Planning (Trimble 2013) was used to estimate GPS satellite coverage at the test area for the periods of the study in terms of position dilution of precision (PDOP) (Figure 2), which represents the effect of GPS satellite geometry on 3D positioning precision. A PDOP value of 1 is associated with an ideal arrangement of the satellite constellation. To ensure high-precision GPS positioning, a PDOP value of 5 or less is usually recommended. In practice, the actual PDOP value is usually much less than

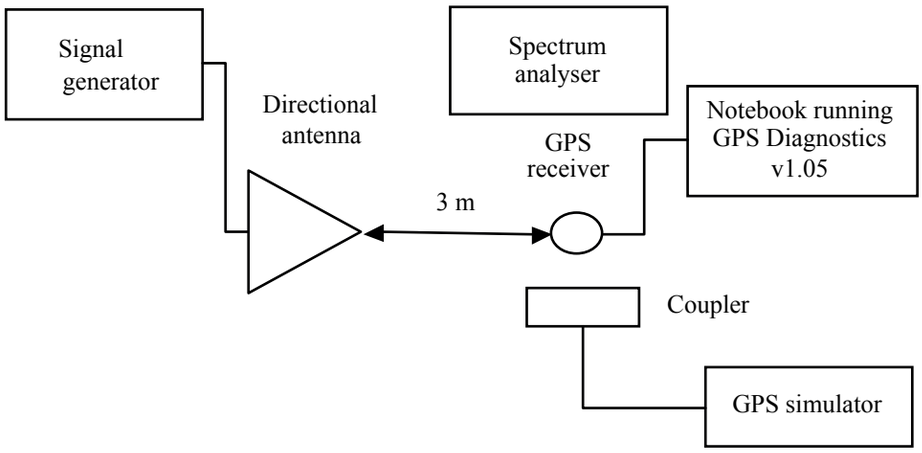


Figure 1. The test setup employed.

5, with a typical average value in the neighbourhood of 2 (DOD 2001; USACE 2003; Kaplan & Hegarty 2006; Huihui *et al*. 2008; Dinesh *et al*. 2010).

The interference signal used was an FM signal with carrier frequency of 1575.42 MHz (the fundamental frequency of the GPS L1 C/A signal), peak deviation of 1 MHz and information frequency of 5 kHz. Once a location fix was obtained with the GPS receiver, interference signal transmission was started at power level of –160 dBm. The power level was increased by increments of 1 dBm. The power levels when the first degradation of accuracy (for this study taken to be the point at which the carrier-to-noise density (C/N_0) levels for GPS satellites tracked by the receiver are less than 35 dB-Hz) and the location fix lost occurred were recorded.

RESULTS AND DISCUSSION

For the locations and UTC times evaluated in the tests, the power levels at which the first degradation of accuracy was noticed and the location fix was lost are shown in *Table 1*. For GPS signal power levels of –151 dBm and –156 dBm, the first degradeation of accuracy occured even before the interference signal was transmitted due to low C/N_0 levels. The reference GPS receiver was unable to obtain a location fix at GPS signal power level of –156 dBm.

It is observed that the interference signal power levels required to affect the location fixes of the GPS receivers are significantly high compared to the corresponding GPS signal power levels. The noise-like C/A code structure, which modulates the L1 signal over a 2 MHz bandwidth, allows for the signal to be received at low levels of interferences. The P(Y) code (restricted to the US military) has a more robust structure, modulating the L1 and L2 signals over 20 MHz bandwidths, and has better resistance to interference. The absence of other error parameters, including ionospheric and tropospheric delays, satellite clock, ephemeris and multipath errors, and unintentional signal interferences and obstructions, resulted in the required minimum jamming power levels in this study to be significantly higher as compared to field evaluations conducted in Dinesh *et al*. (2009a, 2010a,b).

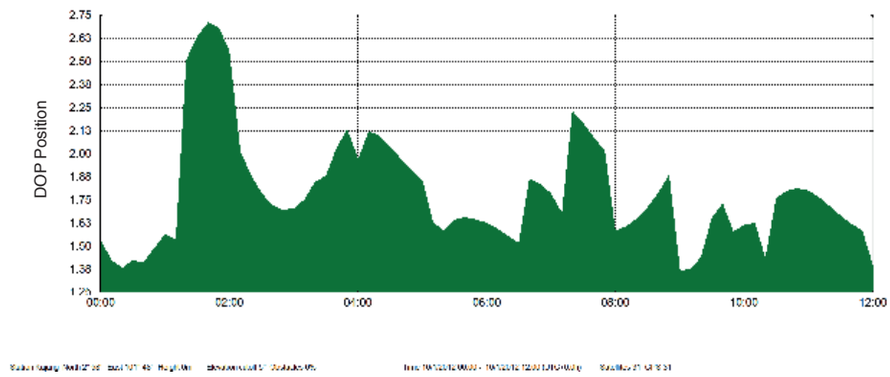
The evaluated GPS receiver has better RFI operability as compared to the reference GPS receiver. This is because the evaluated GPS receiver has higher receiver sensitivity, allowing it to have increased C/N_0 levels for GPS satellites tracked by the receiver, which is the ratio of received GPS signal power level to noise density. Higher C/N_0 levels result in reduced data bit error rate when extracting navigation data from GPS signals, and hence, reduced carrier and code tracking loop jitter. This, in turn, results in less noisy range measurements and thus, better positioning capability (DOD 2001; USACE 2003; Kaplan & Hegarty 2006; Petovello 2009).

It is observed in Figures 3 and 4 that the minimum interference signal power levels required to jam the GPS receivers vary with location and time. This is due to the GPS satellite constellation being dynamic, causing varying GPS satellite geometry over location and time, resulting in the minimum required GPS jamming power level being location/time dependent (DOD 2001; USACE 2003; Kaplan & Hegarty 2006; Huihui *et al*. 2008; Dinesh *et al*. 2010b). In general, the lowest minimum jamming power levels were observed for readings with the highest PDOP values (Kajang at 0300, Denver at 0600, Cairns at 0000 and Rio Gallegos at 0300), while the lowest minimum jamming power levels were observed for readings with the lowest

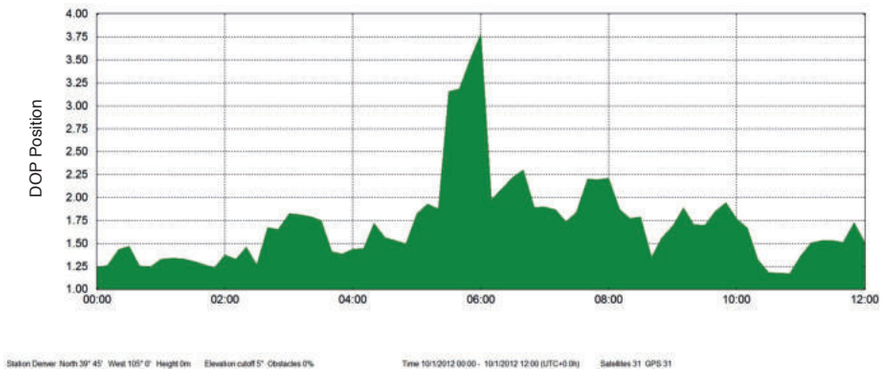
Table 1. Interference signal power levels at which the first degradation of accuracy is noticed and the location fix is lost.

UTC time	Interference signal power level (dBm)															
	GPS signal power level (dBm)	Kajang				Denver				Cairns				Rio Gallegos			
		Evaluated GPS receiver		Reference GPS receiver		Evaluated GPS receiver		Reference GPS receiver		Evaluated GPS receiver		Reference GPS receiver		Evaluated GPS receiver		Reference GPS receiver	
		First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost	First degradation of accuracy	Location fix lost
0000	–131	–90	–73	–88	–83	–88	–73	–88	–85	–91	–75	–86	–81	–90	–71	–86	–82
	–136	–94	–77	–91	–87	–92	–74	–93	–90	–95	–77	–90	–87	–95	–77	–92	–87
	–141	–98	–80	–95	–91	–97	–82	–97	–93	–99	–84	–94	–91	–100	–79	–95	–92
	–146	–105	–84	–104	–99	–105	–84	–103	–99	–108	–88	–99	–94	–105	–84	–104	–101
	–151	–	–90	–	–107	–	–87	–	–103	–	–94	–	–98	–	–88	–	–106
	–156	–	–95	–	–	–	–92	–	–	–	–98	–	–	–	–92	–	–
0300	–131	–90	–74	–89	–85	–89	–72	–82	–78	–91	–70	–81	–76	–91	–74	–90	–86
	–136	–94	–78	–94	–90	–93	–73	–86	–83	–94	–74	–84	–81	–95	–78	–95	–92
	–141	–98	–82	–99	–95	–97	–77	–91	–87	–99	–76	–90	–86	–100	–79	–98	–95
	–146	–106	–88	–106	–101	–107	–82	–96	–92	–107	–85	–94	–91	–109	–86	–104	–100
	–151	–	–91	–	–106	–	–89	–	–101	–	–89	–	–98	–	–89	–	–107
	–156	–	–96	–	–	–	–90	–	–	–	–92	–	–	–	–94	–	–
0600	–131	–90	–72	–90	–85	–89	–74	–90	–86	–91	–70	–83	–80	–86	–69	–80	–77
	–136	–93	–77	–94	–89	–93	–76	–94	–90	–94	–76	–87	–83	–89	–71	–87	–83
	–141	–97	–78	–99	–95	–98	–82	–99	–95	–98	–79	–92	–89	–93	–77	–93	–90
	–146	–106	–83	–103	–98	–107	–85	–104	–99	–109	–85	–96	–92	–103	–79	–100	–96
	–151	–	–88	–	–103	–	–90	–	–106	–	–90	–	–98	–	–84	–	–100
	–156	–	–92	–	–	–	–92	–	–	–	–93	–	–	–	–89	–	–
0900	–131	–90	–71	–86	–82	–89	–72	–90	–85	–91	–73	–86	–81	–89	–70	–86	–82
	–136	–93	–75	–90	–86	–92	–74	–95	–90	–93	–74	–88	–84	–93	–73	–91	–87
	–141	–98	–77	–92	–89	–96	–82	–98	–94	–98	–78	–92	–88	–97	–76	–95	–91
	–146	–107	–83	–97	–91	–106	–84	–103	–99	–106	–86	–97	–93	–108	–81	–101	–96
	–151	–	–88	–	–104	–	–90	–	–105	–	–89	–	–100	–	–88	–	–102
	–156	–	–89	–	–	–	–93	–	–	–	–93	–	–	–	–91	–	–

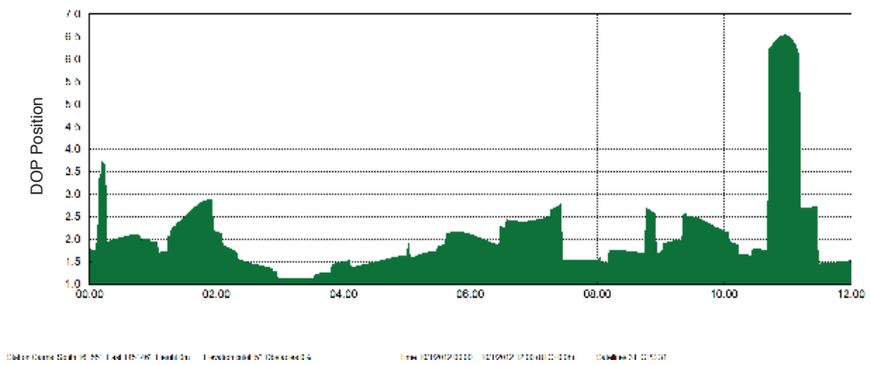
(a)



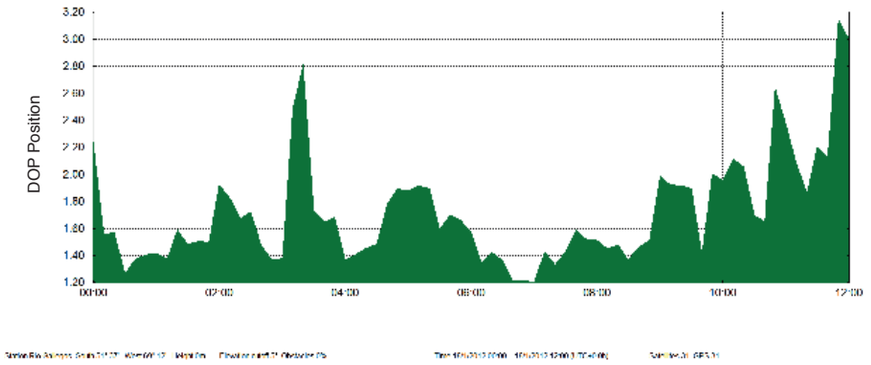
(b)



(c)



(d)



(Source: Screen captures from the Trimble Planning Software)

Figure 2. PDOP of GPS coverage at the test areas for the period of the tests: (a) Kajang (b) Denver (c) Cairns and (d) Rio Gallegos.

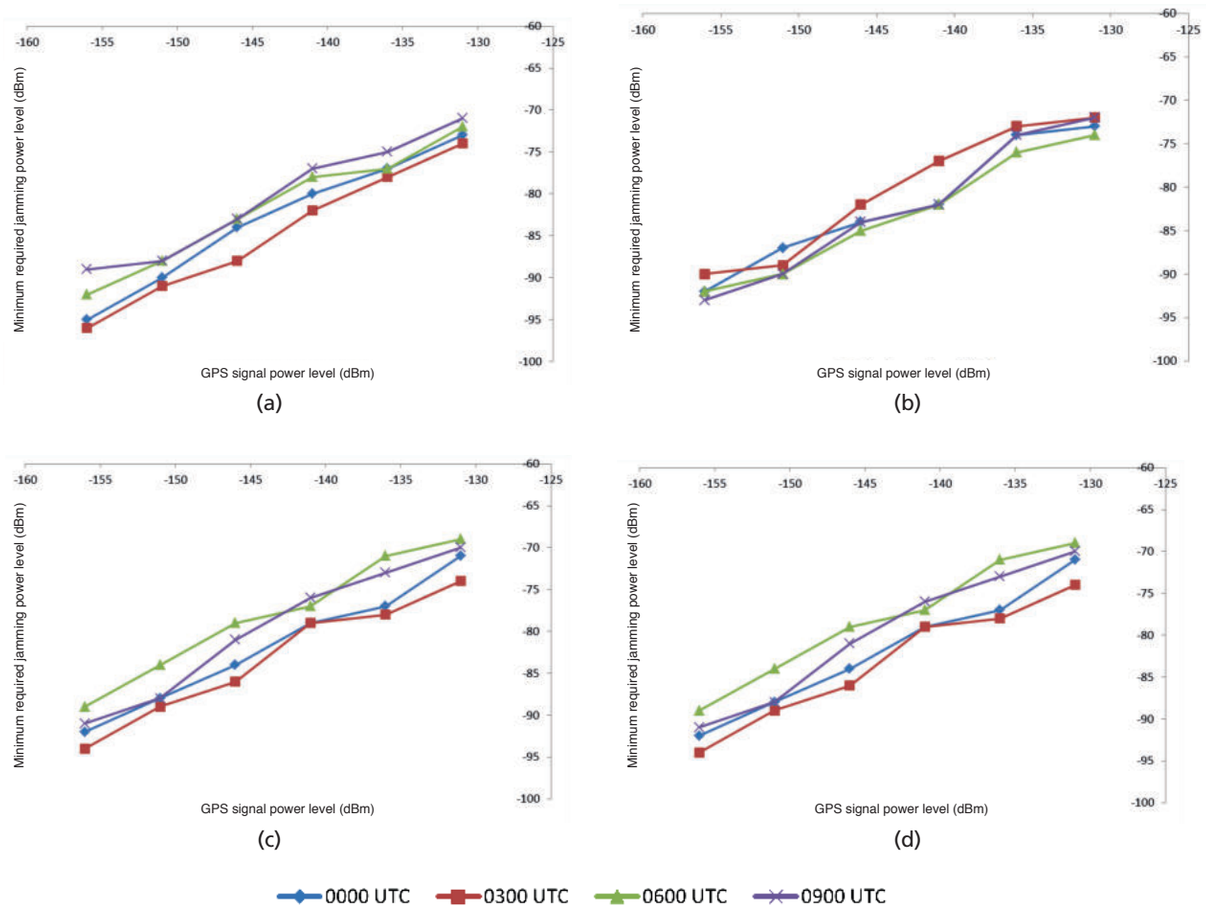


Figure 3. Minimum interference signal power levels required to jam the evaluated GPS receiver at: (a) Kajang (b) Denver (c) Cairns and (d) Rio Gallegos.

PDOP values (Kajang at 0900, Denver at 0300, Cairns at 0300 and Rio Gallegos at 0600).

While this study was focussed on the GPS L1 C/A signal, the findings obtained also are applicable to dual-frequency L1 C/A – semi-codeless L1 P(Y) signals. The quality of receival of dual-frequency L1 C/A – semi-codeless L2 P(Y) depends strongly on the receival of the L1 C/A signal. If the L1 C/A signal is degraded / jammed, the semi-codeless L2 P(Y) signal would also be degraded / jammed. This was demonstrated in a recent study by Universiti Teknologi MARA in collaboration with STRIDE (Norhisyam *et al.* 2013).

CONCLUSION

It was observed that the interference signal power levels required to affect the location fixes of the GPS receivers were significantly high compared to the corresponding GPS signal power levels. The noise-like C/A code structure, which modulates the L1 signal over a 2 MHz bandwidth, allowed for the signal to be received at low levels of interferences. The evaluated GPS receiver had better RFI operability as compared to the reference GPS receiver. This was because the evaluated GPS receiver had higher receiver sensitivity, allowing it to have increased C/N_0 levels for GPS satellites tracked by the receiver. The absence of other error parameters, including ionospheric and tropospheric delays, satellite clock, ephemeris and multipath errors, and unintentional signal interferences and obstructions, result in the required minimum jamming power levels in this study to be significantly higher as compared to field evaluations. The minimum required interference signal power levels required to jam the GPS receivers varied with location and time. This was due to the GPS satellite constellation being dynamic, causing varying GPS satellite geometry over location and time, resulting in the minimum required GPS jamming power levels being location / time dependent. In general, the lowest minimum jamming power levels were observed for readings with the highest PDOP values, and vice versa.

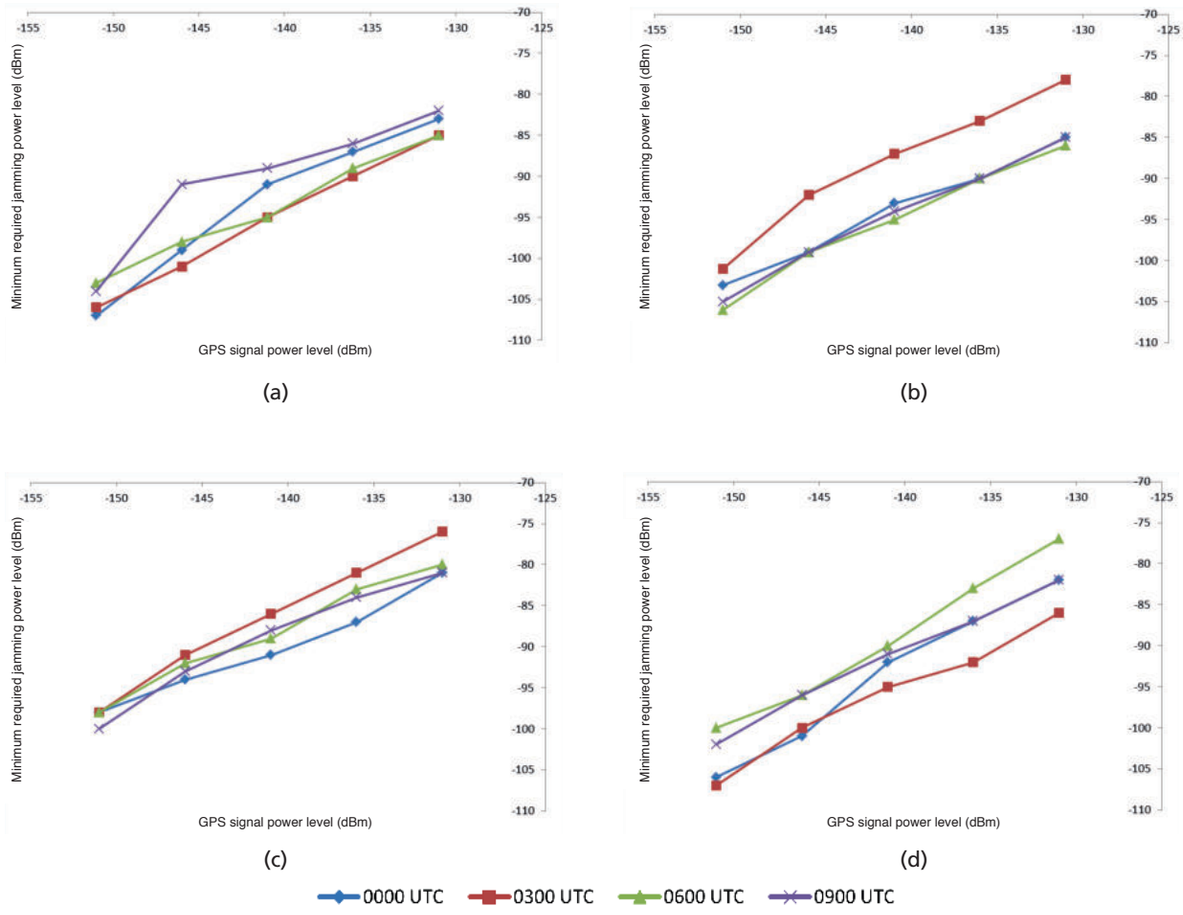


Figure 4. Minimum interference signal power levels required to jam the reference GPS receiver at: (a) Kajang (b) Denver (c) Cairns and (d) Rio Gallegos.

This study had demonstrated the relative ease to conduct GNSS jamming. Low power level interference signals, from intentional or unintentional sources, could cause the disruption of GNSS signals. Given the increasing dependence on GNSS for PNT applications, GNSS disruptions could prove to be problematic, if not disastrous. Hence, GNSS vulnerability mitigations steps should be given emphasis, including navigation/positioning/timing backups, making full use of ongoing GNSS modernisation programmes, increased ability to identify and locate GNSS jammers, integrity monitoring and augmentation, and anti-jamming technologies.

It should be noted that the tests conducted in this study were for ony two GPS receivers from the same manufacturer. Additional tests using a wider range of GPS receivers are needed to further validate the findings of this study. Furthermore, a limitation faced in this study was that the GPS simulator used only allowed the transmission of the GPS L1 C/A signal. The proposed future work is for the procurement of a GNSS simulator that would allow transmission of various GNSS signal frequencies, in order to extend this study to other GNSS systems (e.g. Glonass, Compass and Galileo).

ACKNOWLEDGEMENT

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Simultaneous Co(II)-Titanium(IV) Substitution in Magnetoplumbite-type Barium Ferrite Nanoparticles

G.B. Teh[1]*, Y.C. Wong[2] and R.D. Tilley[3]

Co(II)-Ti(IV)-substituted magnetoplumbite-type (M-type) barium ferrite nanoparticles were synthesized via the sol-gel technique employing ethylene glycol as the gel precursor. Structural and magnetic properties were characterised via X-ray diffraction (XRD), high resolution transmission electron microscopy and superconducting quantum interference device magnetometry. The particle sizes of the M-type $BaCo_XTi_XFe_{12-2X}O_{19}$ ($0.2 \leq \times \leq 1.0$) were found to be 900 Å – 1500 Å. The XRD results confirmed that the Co(II)-Ti(IV) substituted ferrites in the range of $0.2 \leq \times \leq 1.0$ substitution had the M-type ferrite as the dominant phase. The hysteresis loss per-cycle decreased with increasing Co(II)-Ti(IV) substitution in M-type ferrites which showed reduced values in coercivity and remnant magnetisation with moderate effect on the saturation magnetisation.

Key words: Sol-gel growth; nanostructures; hysteresis; magnetic materials; sol-gel technique; ethylene glycol; XRD

Magnetoplumbite-type (M-type) barium ferrite ($BaFe_{12}O_{19}$, BaM) is a magnetic oxide with good chemical stability and mechanical hardness. It has the space group of $P6_{3/mmc}$ (Adelsköld 1938; Smit & Wijn 1959). It is used conventionally as a permanent magnet. However, it has been re-considered as an attractive candidate for use as an ultrahigh density magnetic recording medium without protective layers (Harasawa *et al*. 2010; Matsumoto *et al*. 2010; Nagata *et al*. 2006) due to its large magnetocrystalline anisotropy parallel to the *c*-axis. Substituted BaM compounds have been intensely investigated due to their modified magnetic properties via cation substitutions. The use of BaM as a magnetic recording medium is closely connected with the development of preparation techniques. These preparation techniques require the lowering of the coercivity (H_c) of the pure BaM, which is normally achieved by substituting the Fe(III) ions with, in general, a combination of divalent and tetravalent cations (Teh *et al*. 2007a). Co(II) substitution is of the greatest interest because of its proven large and dramatic effect in reducing the magnetocrystalline anisotropy (Teh *et al*. 2007b). However, lone substitution of Co(II) without tetravalent cations such as Ti(IV) for charge compensation is found to generate structural disorder and oxygen vacancies in the ferrite structure. Nevertheless, the lone Co(II)-substitution reduced the coercivity (H_c) and the saturation magnetisation (σ_s) of the ferrite (Teh *et al*. 2007b).

In our previous work, it was found that simultaneous cobalt-titanium substitution in barium ferrite has reduced the coercivity while retaining the original saturation magnetisation and increasing the remnant magnetic polarisation of the ferrite (Teh *et al.* 2007a & 2007b). However, simultaneous Co(II)-Ti(IV) substitution in M-type barium ferrite ($BaCo_XTi_XFe_{12-2X}O_{19}$) beyond the ratio of X = 1.0 has caused a decrease of saturation magnetisation by 47% (Teh *et al*. 2007a). Surfactant assisted solvothermal synthesis of Co(II)-Ti(IV) substituted BaM in the molar ratio of X = 0.25–1.0 was found to drastically decrease the saturation magnetisation and coercivity of the ferrite (Du *et al*. 2010). Hence, in this study the cation substitution ratio in the sol gel derived barium ferrite is kept within the range of 0.2–1.0.

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Larger particles of magnetic oxides usually exhibit multi-domain magnetism, whereas nano-sized particles characteristically exhibit single domain properties. In this work, an attempt was made to employ ethylene glycol as the gel precursor to synthesise Co(II)-Ti(IV) substituted M-type barium ferrite nanoparticles at 800ºC. The variations in structural and magnetic properties were then systemically investigated.

EXPERIMENTAL

The syntheses of $BaCo_XTi_XFe_{12-2X}O_{19}$ ($0.2 \leq \times \leq 1.0$) were performed using the sol-gel route. Ethylene glycol ($C_2H_6O_2$) was used as the solvent and gel precursor where stoichiometric weights of $Ba(NO_3)_2$, $Co(NO_3)_2.6H_2O$, $Ti(OEt)_4$ and $Fe(NO_3)_3.9H_2O$ were dissolved at the temperature of 50ºC for 2 h with continuous stirring using a magnetic bar. The homogeneous solution was then placed on top of a hotplate with the magnetic stirring bar removed for dehydration process to occur. A viscous gel of high homogeneity was obtained and no precipitation was observed. Slow dehydration of the gel was carried out over 72 h – 96 h at the temperature range of 85ºC–90ºC on a hotplate and subsequently a dried gel was obtained. The dried gel which contained the finely mixed oxides of the starting materials was then calcined at 800ºC (± 20ºC) for 96 h with intermediate grinding after each 24-hour cycle of calcinations, and was quenched in the air.

X-ray diffraction (XRD) patterns were collected from the Philips Diffractometer type PW1710. The Philips system comprised a vertical goniometer without a monochromator, controlled by the Philips PC-APD software. The X-ray tube with a copper target (Kα = 1.54060 Å) was operated at 40 kV and 40 mA. The samples were smeared onto a microscope slide with a droplet of iso-propanol. Routine step scanning was then carried out from 5.0º to 80.0º (2θ) with step size scan of 0.020º/1.5 s (2θ). Chemical composition analysis was carried out by energy dispersive X-ray spectroscopy (EDS) on a JEOL EM-2010 electron microscope. The magnetic properties of the samples were measured with the SQUID, in the range of ±13.5 KG at 300 K.

The HRTEM micrographs of the samples were obtained from JEOL 200CX electron microscope at magnification of 190 000X to 300 000X, after careful corrections of the objective lens astigmatism and incident beam inclination using the granularity of the carbon support film were made. The JEOL 200CX electron microscope was specially modified to include a side-entry stage and high resolution (C_s = 0.41mm) objective lens pole piece (Jefferson *et al*. 1986; Hewitt *et al*. 1989). The microscope was operated with a LaB_6 filament with an accelerating voltage of 200 KeV, giving an interpretable point resolution of about 2.03 Å and an information limit of about 1.8 Å.

RESULTS AND DISCUSSION

The ferrimagnetism of the M-type structure was found to remain within the $0 \leq \times \leq 1$ substitution range. Sol-gel derived specimens for XRD, EDS, HRTEM and SQUID magnetometry measurements were prepared with X values of 0.2, 0.4, 0.6, 0.8 and 1.0.

Figure 1 shows an EDS spectrum for a crystal of $BaCo_1Ti_1Fe_{10}O_{19}$. In the determination of the EDS composition of $BaCo_XTi_XFe_{12-2X}O_{19}$, difficulties arise because of the signal overlaps of Ba Lα with Ti Kα, Ba Lβ with Ti Kβ and the Co Kα with Fe Kβ (Teh *et al*. 2007a). To overcome these problems, standard specimens of BaO and $CoFe_2O_4$ were examined and the standard ratios of Ba Lα/Ba Lγ , Fe Kα/Fe Kβ and Co Kα/Co Kβ were determined (See Table 1). By simple multiplication, the net value of the Co Kα signal could then be determined from that of the Co Kβ peak and the known intensity ratio of 7.4 (4). The net areas of the Ba Lα and Ti Kα peaks were measured as a combined peak and the ratio of Ba Lα and Ti Kα against Co Kα and Fe Kα was then determined accordingly. As seen in the Figure 1, the net area detected for Co Kβ was relatively small. The analyses were plotted to check their consistency and the results are shown in Figure 2 with Table 2 showing the summarised EDS results from the series of specimens. In each of the EDS analysis, a data collection on at least 25–30 crystals was carried out.

Graphs in Figure 2 shows the overall results of EDS analyses for x = 0.2–1.0. The marked lines represented the theoretical ratio corresponding to the pure M-type ferrite. In cases where the ratios of Fe Kα against Ba Lα and Ti Kα were far off the theoretical line, the ratio value was omitted from the calculation in determining the final average ratio of Fe(III) against Ba(II) and Ti(IV). Using these criteria to maintain a low standard deviation in the calculation, about 60%–70% of M-type ferrites were selected in the specimens of Co(II)-Ti(IV)-substituted $BaCo_XTi_XFe_{12-2X}O_{19}$ (x = 0.2–1.0). However, as the molar ratio of Co(II)-Ti(IV) involved in the substitution process was relatively small compared to that of Fe(III), the calculation unavoidably incurred much larger errors which are shown in the standard deviations calculated. Nevertheless, the EDS analyses confirmed the incorporation of Co(II)-Ti(IV) into the structure of the magnetoplumbite-type ferrites.

The XRD patterns confirmed that all specimens lying in the range of $0.2 \leq \times \leq 1.0$ had the M-type ferrite as the dominant phase. Figure 3 shows the characteristic peaks of (110), (107), (114) and (203) planes of a typical highly crystalline M-type hexagonal ferrite phase. The XRD patterns were indexed on the basis of the magnetoplumbite structure retaining the $P6_{3/MMC}$ space group and JCPDS Files (43-0002, 40-1047 and 33-1340) had been referred to for the peak positions identification. The lattice cell parameters were refined using least square refinements

Table 1. Observed line ratios derived from the EDS standards.

EDS Standards	Ratio determined	Ratio of crystals analysed
BaO	Ba-Lα/Ba-Lβ = 1.82(3) Ba-Lα/Ba-Lγ = 10.7(5) Ba-Lα/Ba-LΩ= 16.1(1.0)	25/25
TiO	Ti-Kα/Ti-Kβ = 7.3(2)	21/21
$CoFe_2O_4$	Co-Kα/Co-Kβ= 7.4(4)	32/32
$BaFe_{12}O_{19}$	FeKα/Fe-Kβ = 7.4(1)	20/26

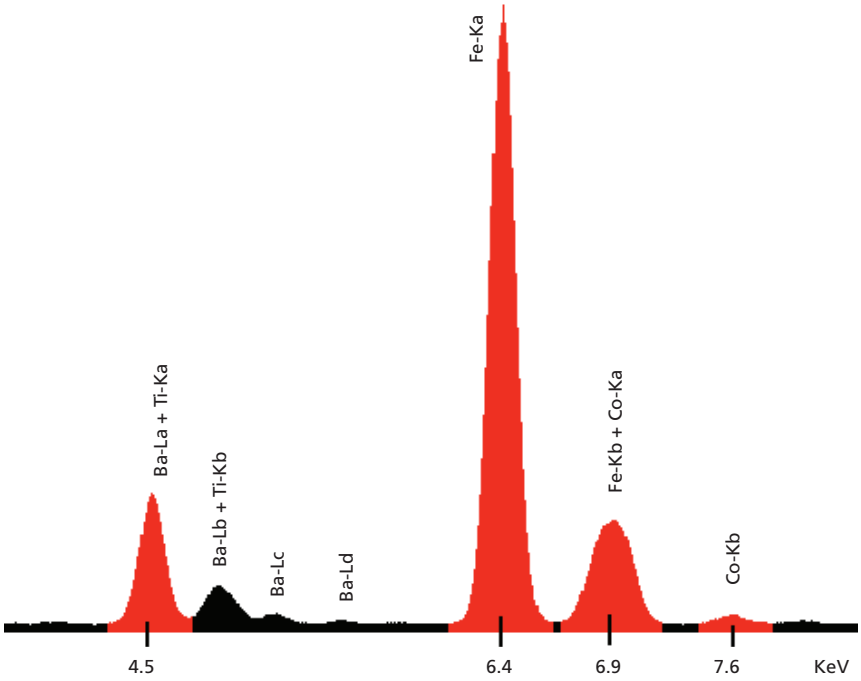

Figure 1. EDS spectrum for $BaCoTiFe_{10}O_{19}$.

methods (Rietveld 1969). The XRD patterns showed slight peak asymmetry and it could have been caused by anisotropic peak broadening and stacking faults in the ferrite structures (Stephens 1999; Dutta *et al*. 1997).

The average particle size of the samples in this study was deduced from the width at half height of XRD maxima by applying the Scherrer's equation (Wold & Dwight 1993).

$$D = \frac{K\lambda}{\omega\cos\theta} \quad (1)$$

where, λ is the wavelength of X-rays, θ the Bragg angle and ω is the full width at half maximum in radian. K varies with (h k l) and crystallite shape but usually nearly equal to 0.9. In the sol-gel derived system of $BaCo_XTi_XFe_{12-2X}O_{19}$ ($0.2 \leq \times \leq 1.0$), the calculated particles sizes were found to be in the range of 900 Å – 1500 Å, as shown in Table 2.

The lattice constants showed relatively little variation in this range. The value of ***a*** was almost constant within the limits of experimental error, whereas ***c*** decreased slightly at first but then returned to its initial value. The axial ratio therefore displayed the same behaviour. Little significance could be drawn from the apparent variation, especially as the observed peaks were relatively broad. However, an examination of c/a parameter ratio may be used to quantify the structure type, as the M-type structure can be assumed if the ratio is observed to be lower than 3.98. A closely related β-alumina ($NaAl_{11}O_{17}$) structure gives a ratio of over 3.98, generally around 4.0–4.1. As shown in Table 2, the c/a ratios calculated for the parent ferrite and substituted ferrites ranged from 3.9363 – 3.9471, all well within the ratio range of M-type structures (Yamamota & O' Keeffe 1984).

The SQUID results and curves are shown in Table 2 and Figure 4, respectively. At the composition of the

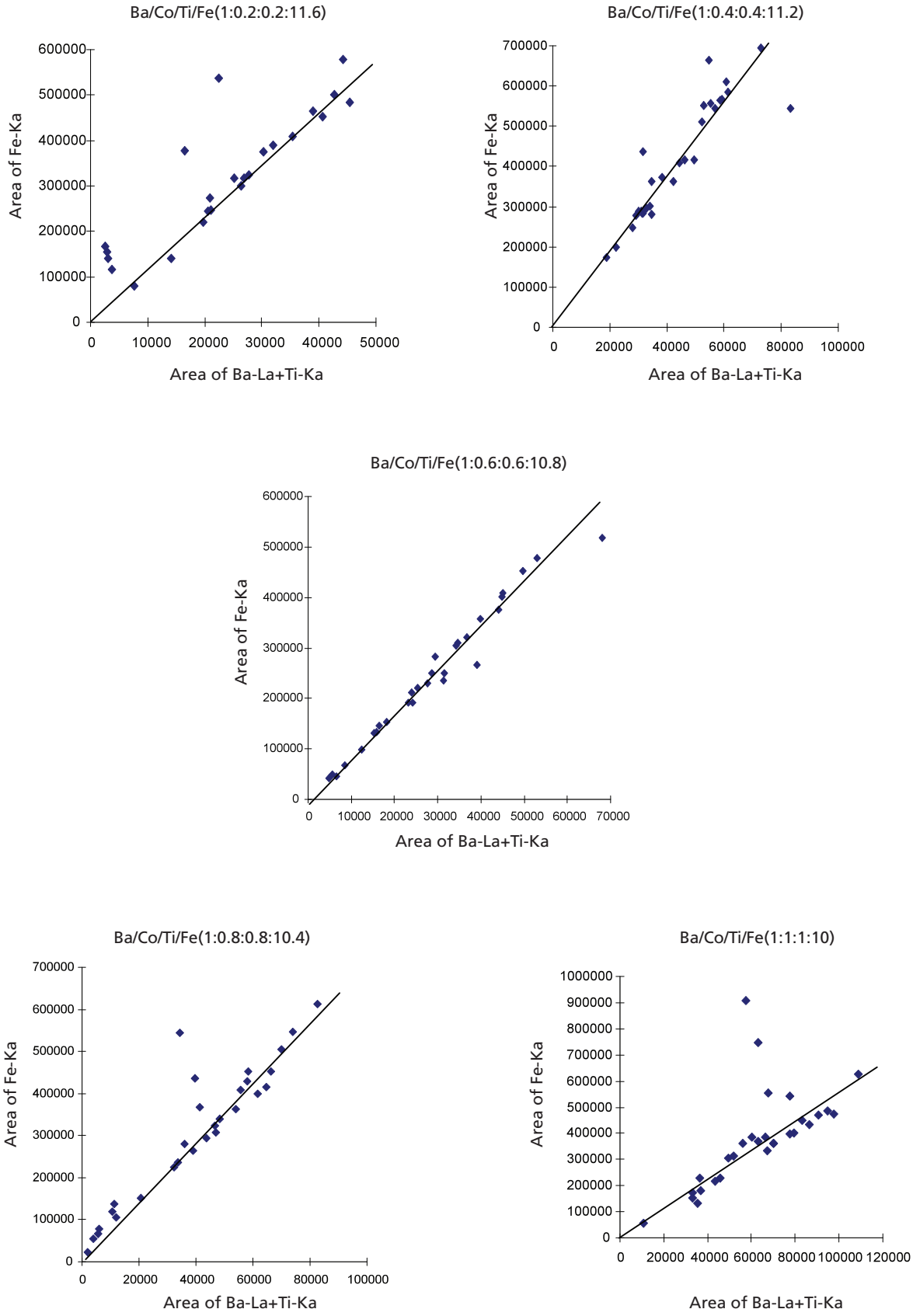

Figure 2. Graphs showing the area of Fe Kα versus area of Ba Lα + Ti Kα in the system of $BaCo_XTi_XFe_{12-2X}O_{19}$ for selected samples in the range of X = 0.2–1.0. (Marked line indicated the theoretical M-type ferrite ratio).

Table 2. EDS Composition, particle sizes, refined lattice constant parameters and SQUID magnetometry measurements of the system $BaCo_XTi_XFe_{12-2X}O_{19}$ ($0 \leq \times \leq 1$)

EDS Composition of Ba/Co/Ti/Fe	% Crystals analysed	Calculated lattice constant parameters			Ratio of C/a	Calculated particle size (Å)	Hc (G)	σ_r (emu/g)	σ_s (emu/g)
		a (Å)	C (Å)	V					
*$Ba_{1.0}Fe_{11.8(9)}$	96.0	5.898(2)	23.28(2)	701.2(6)	3.9471	363.0	1082	25.0	47.8
$(Ba,Ti)_{1.2}Co_{0.11(8)}Fe_{13.9(7)}$	66.7	5.899(2)	23.22(2)	699.7(5)	3.9363	1450.0	736	25.1	54.2
$(Ba,Ti)_{1.4}Co_{0.31(8)}Fe_{12.6(7)}$	66.7	5.896(1)	23.21(9)	698.8(3)	3.9366	928.0	620	16.1	43.1
$(Ba,Ti)_{1.6}Co_{0.5(1)}Fe_{12.9(8)}$	58.6	5.899(1)	23.23(1)	700.2(3)	3.9380	1202.0	370	16.1	44.8
$(Ba,Ti)_{1.8}Co_{0.76(8)}Fe_{12.2(5)}$	58.6	5.895(1)	23.22(1)	698.8(3)	3.9389	1001.0	200	9.3	37.6
$(Ba,Ti)_{2.0}Co_{1.04(7)}Fe_{10.2(6)}$	69.0	5.898(2)	23.28(1)	701.4(5)	3.9471	1070.0	85	3.3	41.5

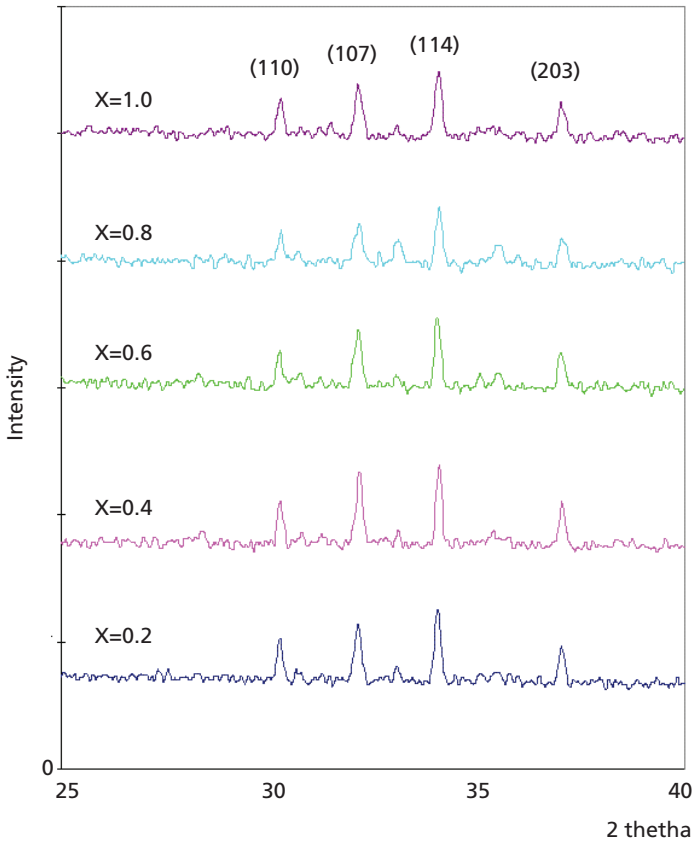

Figure 3. XRD patterns for sol-gel derived $BaCo_XTi_XFe_{12-2X}O_{19}$ ($0.2 \leq X \leq 1$).

x = 0.2 substituted barium ferrite, the hysteresis loop showed a maximum saturation magnetisation at 54.2 (5) emu/g. However, when compared to the parent ferrite, $BaFe_{12}O_{19}$, the coercivity has been lowered by about 32.0% to a value of 736 (30) G. Although the saturation magnetisation plays a crucial role in determining whether the ferrite has a potential commercial application, the value for the coercivity is also of considerable importance. The minimum applicable coercivty is at 630 G, and any drop below this value is not desirable (Edelstein & Cammarata 1996).

The x = 0.4 and 0.6 substituted barium ferrite both showed a similar value of recorded remnant magnetisation with x = 0.6, having a slightly higher value of saturation magnetisation. The x = 0.4 phase however, has a much higher coercivity than the X = 0.6 phase, namely 620 (30) G compared to 370 (20) G. For the soft magnet application, the magnetic properties of x = 0.4 system would produce a better material for recording purposes.

In the x = 0.8 and x = 1.0 substituted ferrites, although the values of saturation magnetisation are moderate,

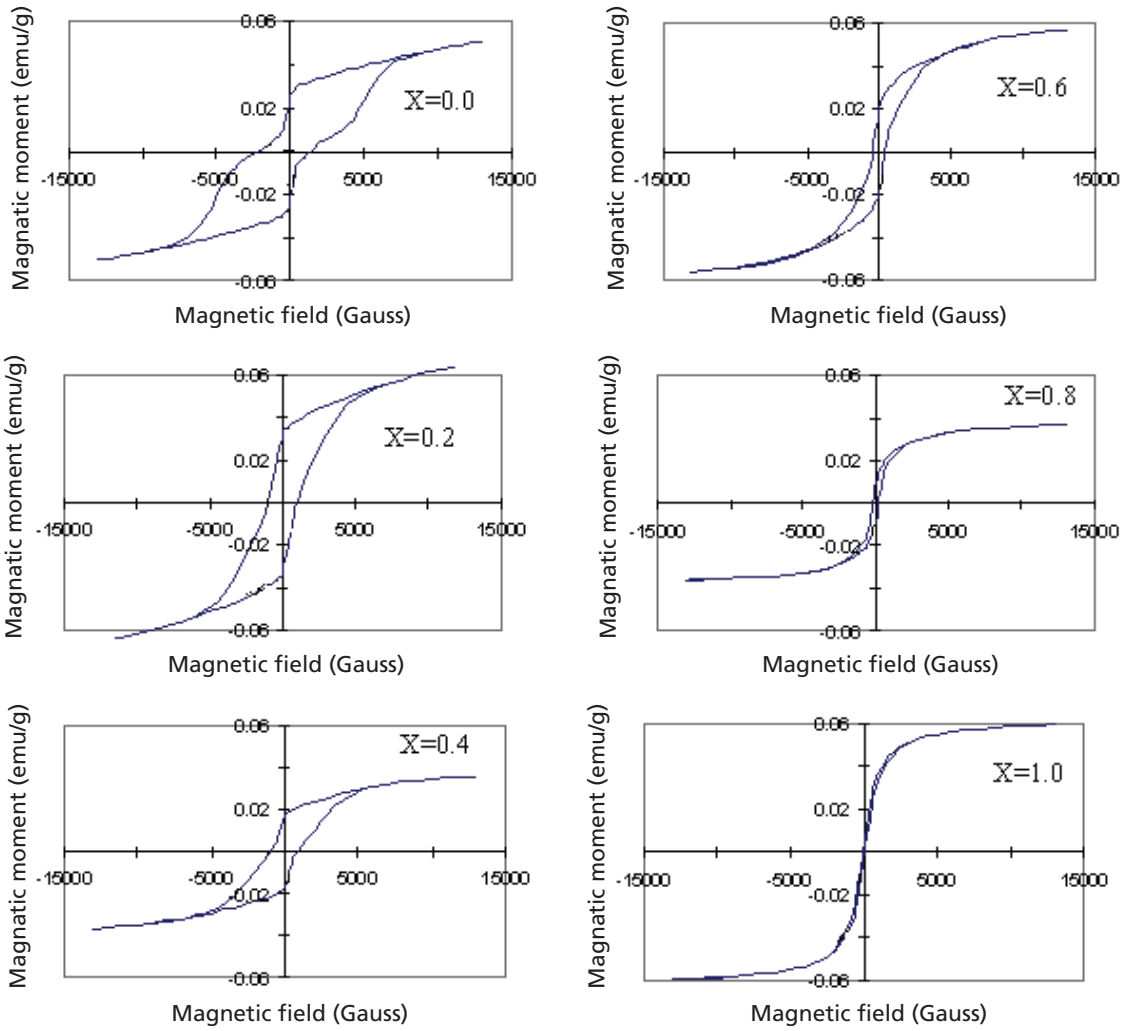

Figure 4. Hysteresis loops of $BaCo_XTi_XFe_{12-2X}O_{19}$ system with ($0 \leq X \leq 1$).

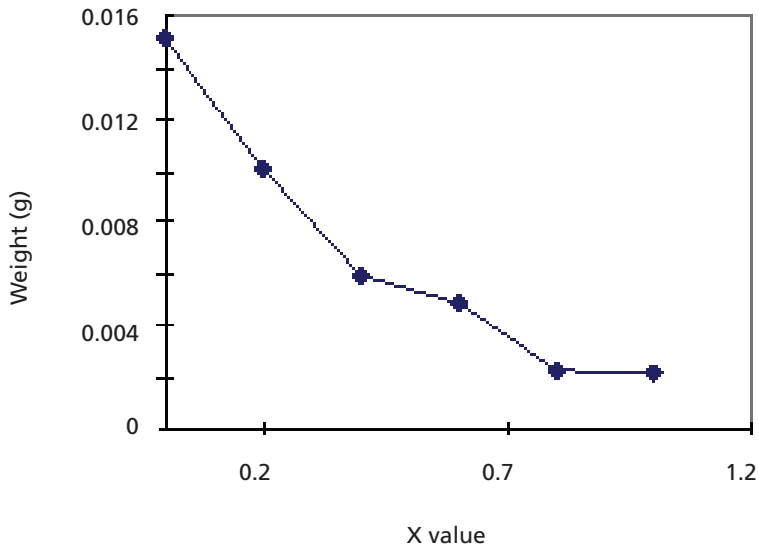

Figure 5. Cut-out weight of the area of hysteresis loops per-cycle in Figure 4.

being in the range of 35 emu/g – 40 emu/g, the value for the remnant magnetisation are much too low for application in a recoding medium, lying in the range of 2 emu/g – 10 emu/g. In general, substitution of Co(II)-Ti(IV) in the range of $0.4 < \times < 0.8$ failed to retain the high saturation magnetisation when compared to the x = 0.2 system. Overall, the hysteresis loss per-cycle (i.e. the area in the hysteresis loop) decreased with increasing Co(II)-Ti(IV) substitution (See Figures 4 and 5). This showed that increasing Co(II)-Ti(IV) substitution reduced the coercivity and remnant magnetisation with moderate effect on the saturation magnetisation. This is ascribed to the lower magnetic moment of Co^{2+} (3 μB) relative to Fe^{3+} (5 μB), while the decrease in coercivity values is due to the reduced magnetocrystalline anisotropy in the substituted M-type ferrites.

Figure 6 shows a crystal from the substitution series where x = 1.0. The micrograph indicated a long range ordering and the long axis of the crystal is perpendicular to the ***c***-axis of the M-type structure. The contrast and fine details of the structure were similar to that of the standard barium ferrite. With the aid of EDS and magnetometry measurements, this confirmed the successful incorporation of Co(II)-Ti(IV) into the structure of $BaCo_1Ti_1Fe_{10}O_{19}$ without significant structural change, as substitution of Co(II)-Ti(IV) did not change the fine structure of the HRTEM image and the calculated lattice parameters remained constant throughout the substitution range.

CONCLUSION

The ethylene glycol method used was found to be capable of producing nano-sized ferrite particles ranging from 900 Å – 1500 Å in size within the system of $BaCo_XTi_XFe_{12-2X}O_{19}$ (with x = 0.2–1.0) with a narrow particle size distribution. HRTEM imaging showed that the Co(II)-Ti(IV) substitution in the system of $BaCo_XTi_XFe_{12-2X}O_{19}$ produced no drastic change in the fine structure of the ferrites. The M-type ferrite examined by HRTEM displayed a long axis perpendicular to the *c*-axis of the magnetoplumbite structure.

It was found that substitution of Co(II)-Ti(IV) with x = 0.2 exhibited an increase in both remnant and saturation magnetisation when compared to the parent ferrite. With the magnetic recording application in mind, it may be concluded that the ferrite with the substitution range of x = 0.2–0.4 in the sol-gel derived system of $BaCo_XTi_X Fe_{12-2X}O_{19}$ have a potential commercial application. Overall, the hysteresis loss per-cycle decreased with increasing Co(II)-Ti(IV) substitution where the values of coercivity and remnant magnetisation were decreased while the saturation magnetisation was relatively unaffected.

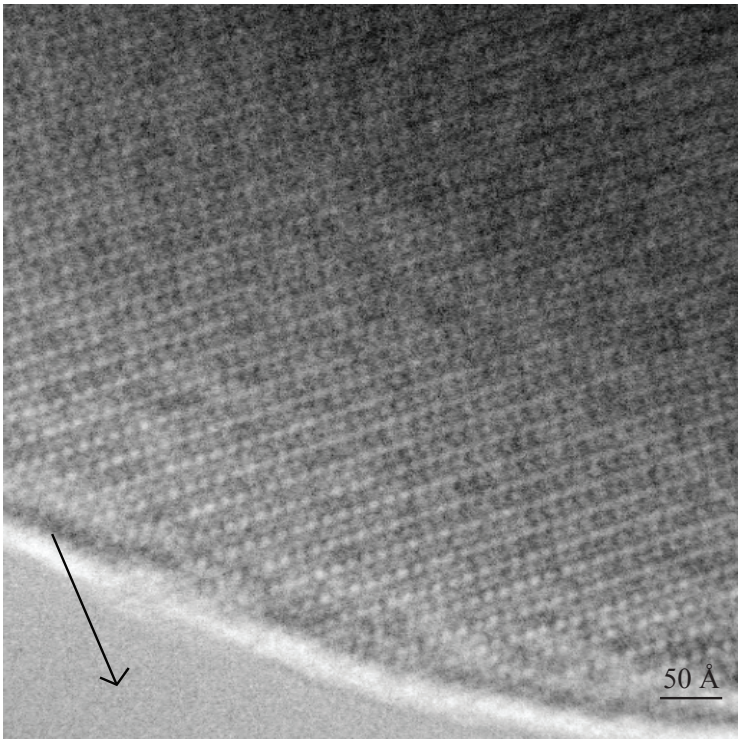

Figure 6. Micrograph of a crystal of $BaCo_1Ti_1Fe_{10}O_{19}$ (Arrow showing the direction of *c*-axis).

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Microfluidic Systems for Dielectrophoretic Separation of Fluorescent Particles

N.A.M. Yunus[1], H. Jaafar[1], I.A.Halin[1] and N.G. Green[2]

This paper presents a suitable and unique system for observing dielectrophoretic particle separation in a microfluidic device. Details presented on the experimental setup used will enable real time examination, monitoring and analysis of carboxylate-modified latex sphere particles in a colloidal mixture. Observations of the particles were made possible through an optical setup that illuminates the particles that went through the microelectrode array in the microchannel that was controlled by two analog signal generators. Through the setup, it was easily observed that the latex sphere particles move at a flow rate of 0.2 µl/s without colliding or overlapping on each other and successfully separated in two bands left and right. The new separation of one finest particles size for finest purification with respect to frequency was also observed, obtained and analysed.

Key words: Microfluidic, experimental setup, dielectrophoresis, separation; carboxylate-modified latex; purification

Dielectrophoresis (DEP) is a phenomenon observed when a dielectric particle is subjected to force from a non-uniform electrical field (Pohl & Crane 1971; Pohl 1978). The behaviour observed has proven to be strongly related to the particle's electrical properties, shape and also to the electric field's frequency. Under controlled conditions, DEP has been used in experiments for microsized and nano-sized particle separation and sorting in colloids (Green & Morgan *et al*. 1997; Morgan & Hughes *et al*. 1999, Morgan & Morgan *et al*. 2003, Holmes & Morgan *et al*. 2006). A microfluidic channel is a device that contains small liquid guides constructed with or without microelectrodes with dimensions comparable to living biological cells and are often used in DEP experiments (Dittrich & Manz 2006, Ohno *et al*. 2008). As a result, new microfluidic DEP particle separation research are emerging and demand unique experimental procedures, which highly depend on the type of particle under study. This experimental setup must also allow a clear visualization of the particles in real time.

Conventionally, visualization of the separation phenomena is observed on a video screen in black and white. This paper will highlight the experimental setup that allows clear observation of the separation event of small particles ranging between 1µm and 500 nm in radius. These particles are fluorescents and can be excited to emit florescent light. The paper also will show the separation of the finest particles size for finest purification with respect to frequency. Hence a new experimental system to view fluorescent particle separation using the particle-emitted florescence is demonstrated and proven in this work.

V-shape Microfluidic Device Construction

Figure 1 shows the schematic of the microfluidic device of V-shape designed for this experiment. A 60º inclined microelectrode arrangement is used to generate a non-uniform electric field (Yunus & Green 2008). Each electrode is approximately 20 µm wide and fabricated using a microfabrication process where titanium/palladium/aurum is used. The dimensions of the microelectrodes are each approximately 10 nm/10 nm/100 nm, respectively (Green *et al*. 1997). The dimensions of the microfluidic channel length, width and thickness is 10 mm, 500 µm and

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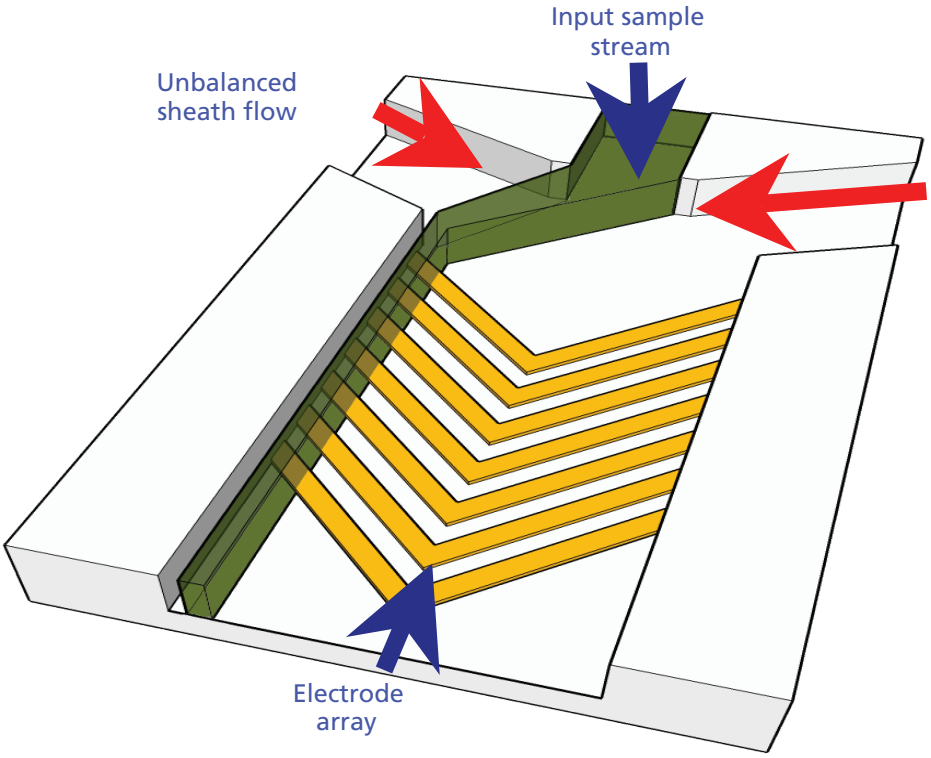

Figure 1. Microfluidic device: A schematic design of fabricated V-shape microfluidic device.

40 µm, respectively (Yunus *et al*. 2011). Three inlets and two outlets are created using a negative photo-penetrable dry film epoxy through an etching process and the side inlets are used for hydrodynamic focusing of the particles (Yunus & Green 2010). They are used to control the sheath flow to only one side of the device (near sidewall) because the DEP force is strongest at the sides of this particular channel. DEP force in the center is at its weakest (Yunus *et al*. 2010).

The electrodes are bonded onto a glass substrate measuring approximately 1.1 mm thick. Glass is chosen because it is chemically inert to a majority of liquids and gasses, hydrophilic and 100% optically clear. It also allows visualization of the DEP experiment. The total thickness of the bonded microelectrodes array chip is approximately 2.20 mm thick.

Optical Setup

Figure 2 shows the optical setup for particles that are able to emit fluorescent light. This setup enables a real time visualization of the DEP experiment. It uses a simple combination of optical instruments and has never been set by others. The setup consist of a blue LED light source which was used to form a light beam focused through a 300 mm lens with objective 20 (× 20) and through an excitation filter producing a constant blue beam with wavelength of 450 nm. A dichroic filter reflects the blue beam towards three angled mirrors towards the sample in the microchannel via a 10 (× 10) objective lens. This blue light beam causes the particles under test to emit a green fluorescent illumination. At the same time, a white light source is placed under the sample and it is used as an aid to visualize the flow of the particles into the microchannel. Both white and green light beams are reflected back through the three angled mirror arrangement and through the dichroic filter that only allows the particle's green fluorescent light to pass through. This green beam carrying the signal is subjected to an optical bandpass filter, passing only light with wavelength of 555 nm that is finally focused through a 200 mm lens into a video camera for observation.

Test Particles Preparation and Separation

This experiment commences by identifying the latex sphere particle sizes which are prepared in one set of mixture containing particles of radius 1 µm and 500 nm called Set A and only 1 µm in radius ± 0.9% in Set B. These particles are chosen because they are standard test particles used in experiments conducted by chemist and biologist to identify and ensure that a certain device is working properly (Yunus & Green 2009).

The device is packaged by establishing fluidic interconnects using Omnifit T-junctions, 1/16" PTFE (*Teflon*)

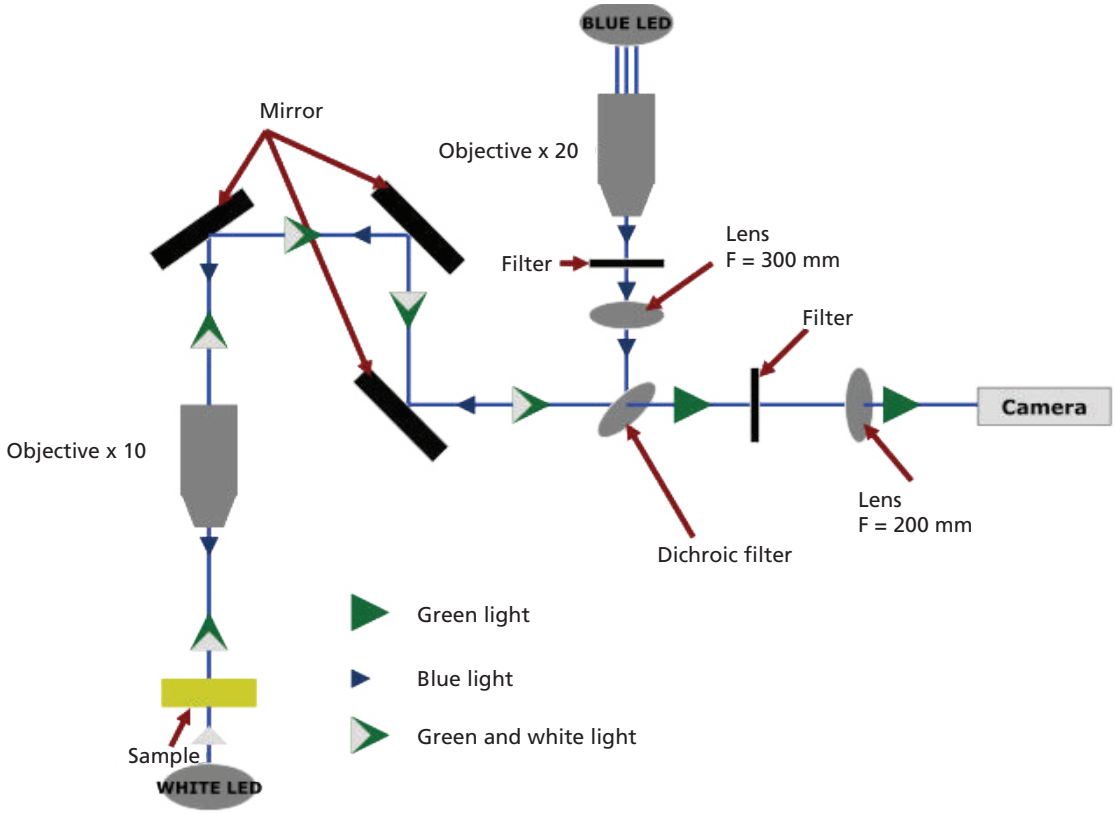

Figure 2. The microscope setup used for the observation of the microfluidic device. The dichroic filter is to reflect the white light and pass through the green light to the camera. Blue light comes from the LED is to form a beam of blue light straight to the objective of times 20. This beam of light is then passed through the lens of 300 mm straight to excitation filter that only pass the excitation wavelength down to the dichroic filter. The sample is then excited by the blue light and emit the greenlight to times 10 objective straight to dichroic. The filter is the emission filter that only allows the emission wavelength passes through it. Therefore the green light could pass the filter. The white light underneath the sample is used to enable visualisation.

tubing fitting with inner diameter of 0.5 mm. In order to avoid recurrent regulation at low flow rates, a 250 µl glass syringe is used which is in size with that manufactured by Hamilton-Bonaduz Schweiz the Gastight #1725®.

In the experiment, the hydrodynamic focusing technique is used by flowing two-sheath flow from the sides and the sample flow (the main flow) in the middle. It is a technique that allows the focus of a sample stream into an accurately controlled detection/measurement region to ensure reliability and reproducibility. It is observed that the latex sphere particles move at a very low flow rate of 0.2 µl/s without colliding or overlapping on each other.

RESULTS

The optical setup has resulted in a clear visualization of the separation phenomena for Set A. Under an applied electrode potential of 17 Vpp, a stream of particles flow near the left wall of the device while another stream flows near the right wall. The two individual particles and their respective position were determined by recording particle motion at the exit of the microfluidic device at different field frequency and conductivity. The recording view is at the tips of the V-shape microelectrodes, which is closer to the exit of the microfluidic device.

Figure 3 shows the results for the two-particle mixture separated clearly. The particles intensity is used to represent the particle size while distance is the size of the microfluidic channel width. The results observed under two sets of conductivity conditions where in the first condition, the particles are subjected to a conductivity of potassium chloride, KCl, 1.4 mS/m (100 µM) [Figures 3(a)−3(c)]. In the second condition, the second row of the diagram, the particles are subjected to a conductivity of KCl of 14.8 mS/m (1 mM) [Figures 3(d)−3(f)]. The two figures reveal that the separation distance increases as conductivity increases. This is clearly observed by comparing plots in Figures 3(a) and 3(d). Figures 3(g)−3(i) show the plots at higher frequencies. In our inspired results, an increase in the conductivity by approximately 10 times mS/m would increase the separation distance by ±50 µm.

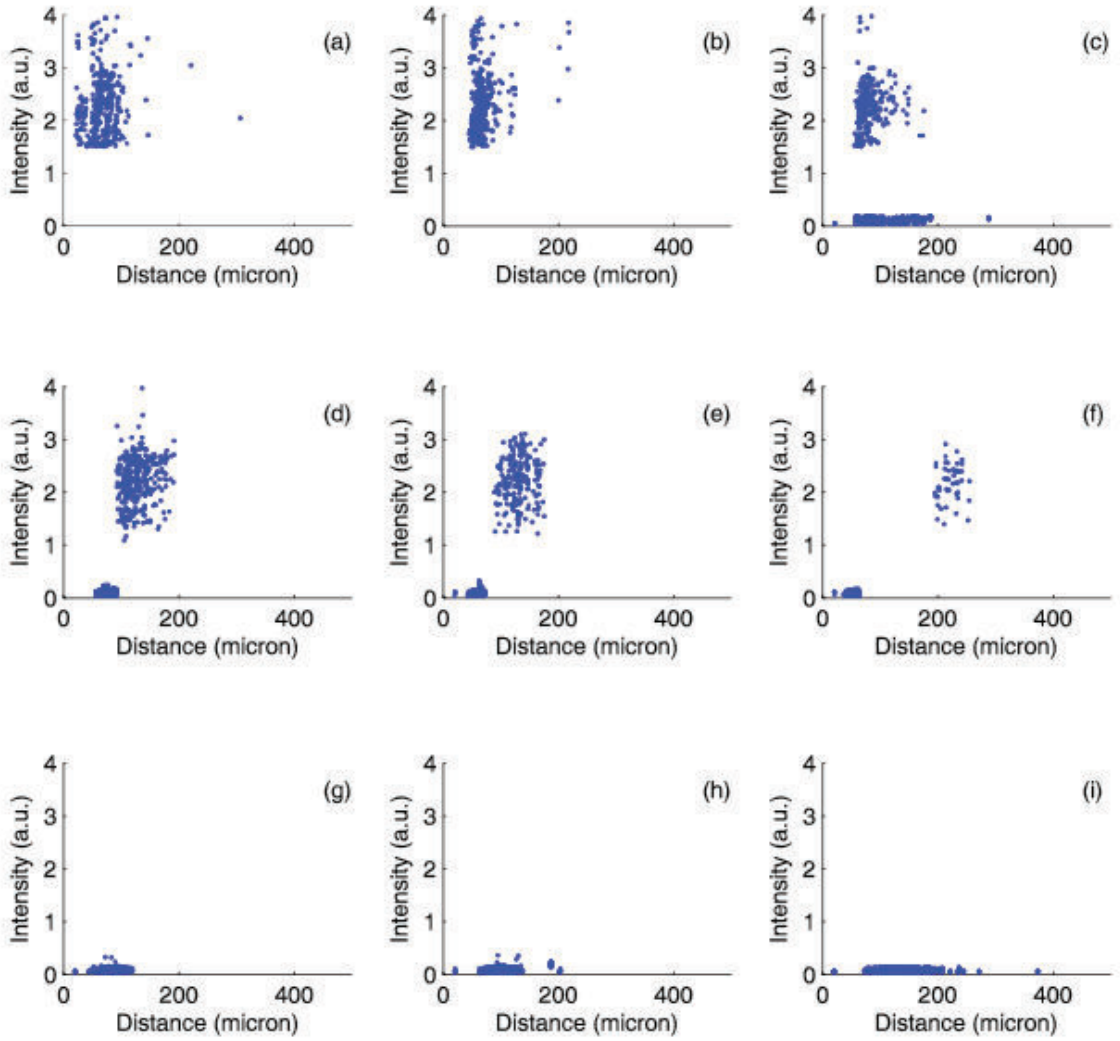

Figure 3. Analysis plots of the intensity and position of the component of the mixture at the exit array. The intensity represents the particles size. The graphs show the separation of two sizes of particles suspended in KCl of 1.4 mS/m at voltage 17 Vpp: (a) 500 kHz, (b) 600 kHz, (c) 700 kHz. The second row, particles suspended in KCl of 14.8 mS/m at (d) 500 kHz, (e) 600 kHz, (f) 1 MHz, (g) 5 MHz, (h) 10 MHz, and (i) 20 MHz.

The other new experiment performed is ultra-fine purification where the colloidal mixture of Set B is used. Initially, the particles are coated with gold/palladium to clear them of stray charge and examined under a scanning electron microscope (SEM) to measure their radius. The results shows that a cluster of mixed particles with a variety of sizes as shown in Figures 4 and 5.

When the sample is fed through the microfluidic channel, it is observed that the effect of the frequency and voltage applied to the electrode array deflects the 1µm particles over the lateral line at the end of the array. The distance of 1 µm particles from the sidewall versus distance across the lateral channel is plotted as shown in Figures 6–8. From these graphs, it shows that the 1 µm particles are deflected farther from the wall when the frequency is increased. The deflection is not strong in a lower conductivity medium and lower range of applied voltage. However, at higher applied voltage the deflection of the particles increases dramatically as shown in Figure 6. It rises especially at the intermediate frequency range between 7 MHz – 10 MHz. At 10 MHz and above, the deflection starts to decrease due mainly to voltage attenuation. Figure 7 shows that the 1µm particles are deflected further when higher voltage is applied (Yunus *et al.* 2013). However, in Figure 8 it is observed that the number of particles is less than expected when a 10 MHz frequency is applied. This is due to particle entrapment behind V-shaped electrodes. The graph also shows the skew in the intensity of the particle, which we would declare that the larger particles deflected and elude first from the arrays and the smaller size were trapped due to higher negative DEP force.

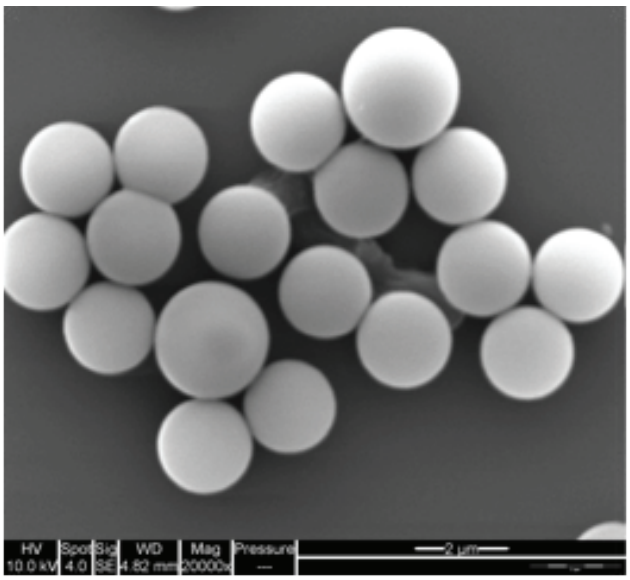

Figure 4. Image of the fluorescent 1 µm in radius particles (first sample) of different size captured under scanning electron microscope (SEM), the FEI Quanta 200 SEM (FEI Company, Eindhoven, Netherlands).

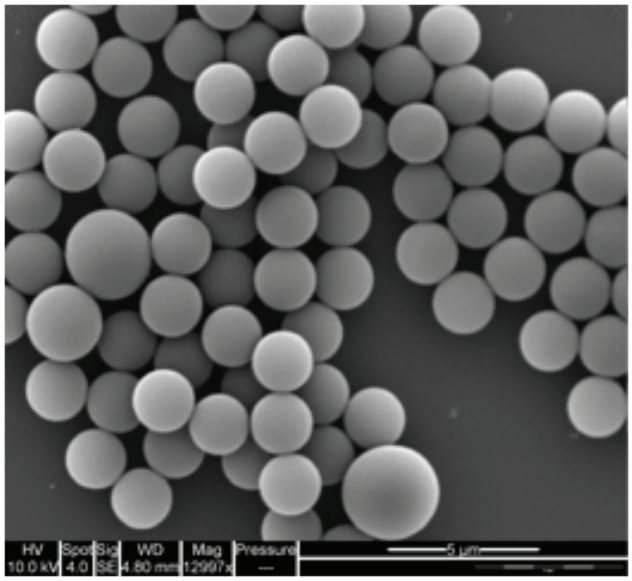

Figure 5. Image of the fluorescent 1 µm in radius particles (second sample) of different size captured under scanning electron microscope (SEM), the FEI Quanta 200 SEM (FEI Company, Eindhoven, Netherlands).

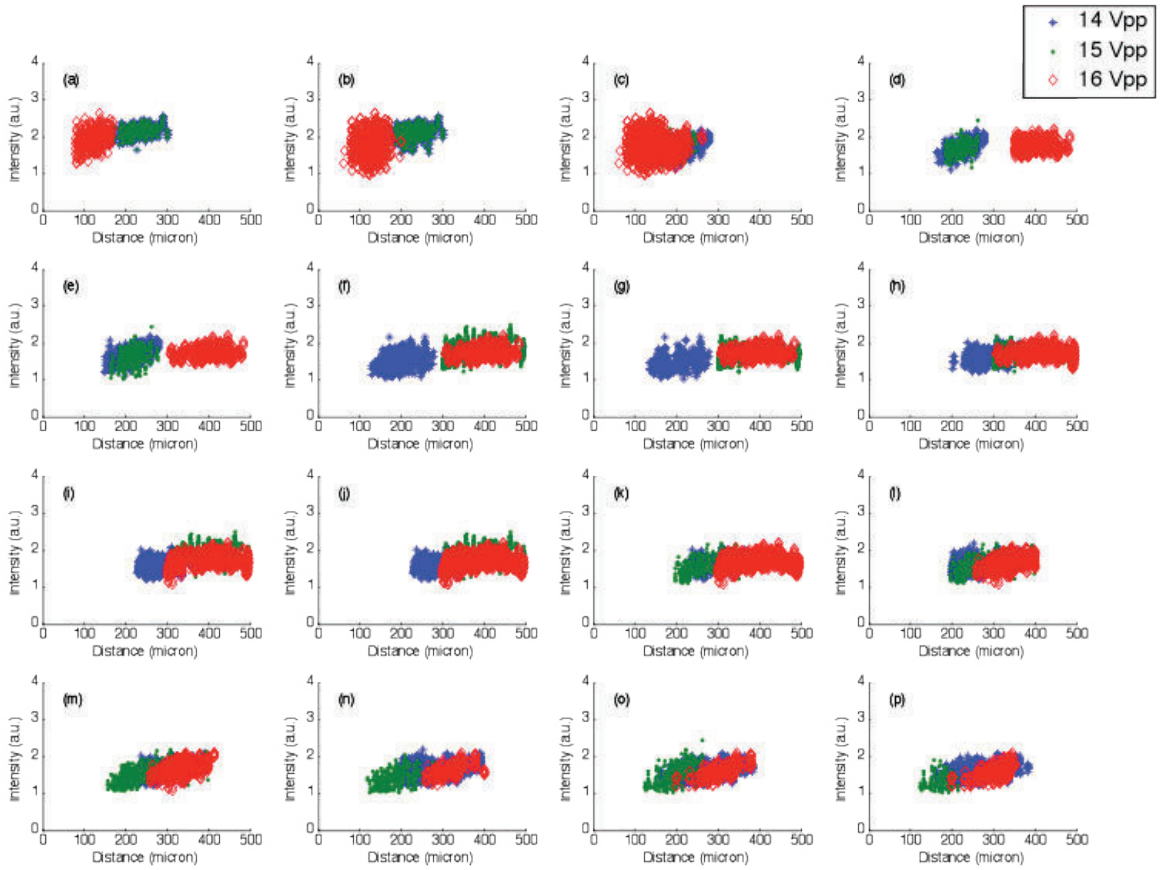

Figure 6. Deflection of 1 µm in 100 µM at 14 V, 15 V, 16 V with frequency (a) 1 MHz (b) 2 MHz (c) 3 MHz (d) 4 MHz (e) 5 MHz (f) 6 MHz (g) 7 MHz (h) 8 MHz (i) 9 MHz (j) 10 MHz (k) 11 MHz (l) 12 MHz (m) 13 MHz (n) 14 MHz (o) 15 MHz (p) 16 MHz. The distance of 1 µm particles is changed within this range of frequency of a given applied voltage.

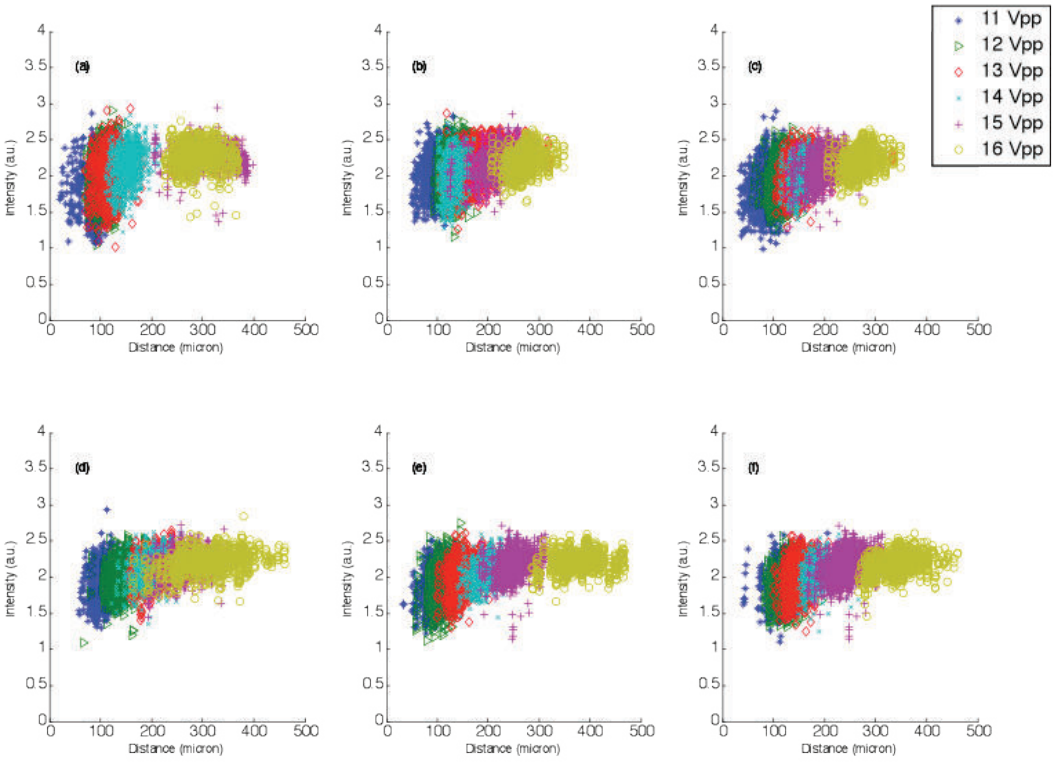

Figure 7. Deflection of 1 μm at maximum 16 V 1 mM solution, 11 V, 12 V, 13 V, 14 V, 15 V, 16 V, with frequency of (a) 1 MHz (b) 2 MHz (c) 3 MHz (d) 4 MHz (e) 5 MHz (f) 6 Hz. The distance of 1 μm particles is changed within this range of frequency of a given applied voltage.

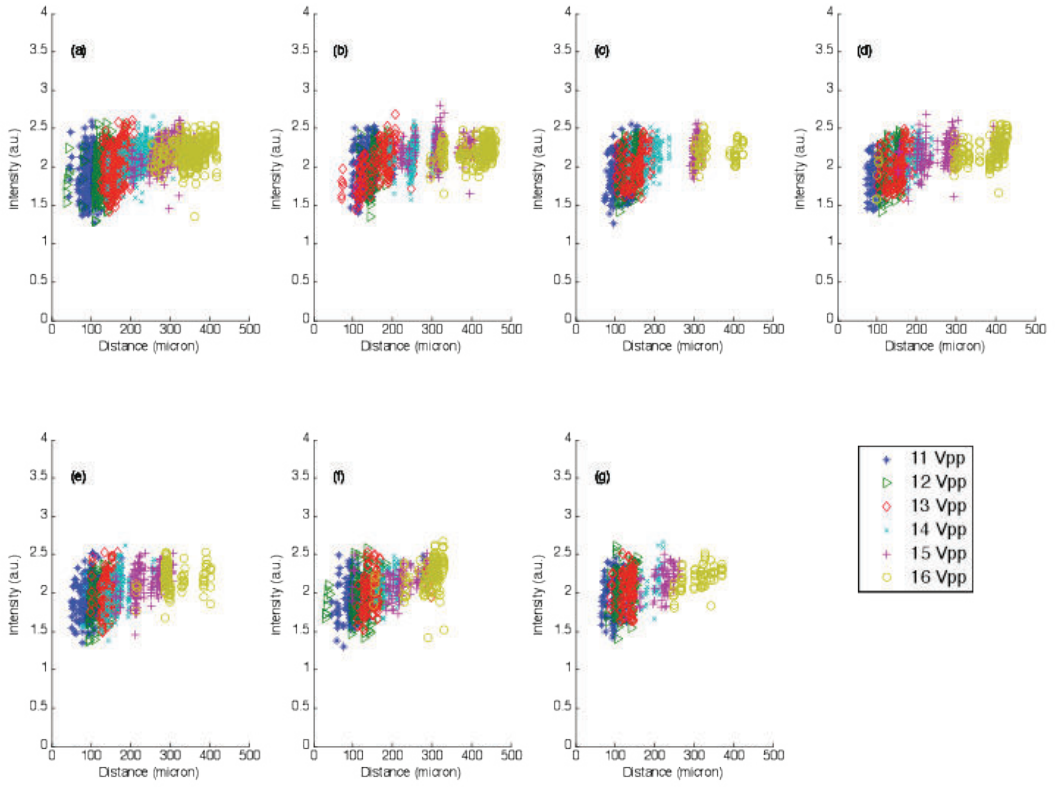

Figure 8. Deflection of 1 μm at maximum 16 V 1 mM solution. The graphs show range of voltages 11 V, 12 V, 13 V, 14 V, 15 V, 16 V with frequency of (a) 10 MHz (b) 11 MHz (c) 12 MHz (d) 13 MHz (e) 14 MHz (f) 15 MHz (g) 16 MHz. The distance of 1 μm particles is changed within this range of frequency of a given applied voltage.

The advantage of this deflection study is the verification of the effectiveness of the system to deflect 1 µm particles by ± 0.9%. Thus, with the results shown, we could identify that in KCl with 1mM medium conductivity, 1µm particles can be deflected very well from a clusters of similar particles ranging in size when a separation frequency between 1 MHz – 5 MHz is used. It also shows that random separation occurs when the frequency exceeds MHz as shown in Figure 8. This behavior is not evident for the 100 µM particles as they experience weaker DEP force due to their large size. Therefore, the DEP force tends to react on the whole cluster as a single particle.

DISCUSSION AND CONCLUSION

The optical setup designed with simplicity, and cost effectiveness in this work was proven to obtain excellent clarity for clear observation of particle separation. By the incorporation of a proper optical setup to observe the DEP separation phenomena, machine vision could be incorporated to the experimental setup, hence allowed automatic data acquisition. The system allowed the observation of successful DEP separation for the separating/filtering of finest 1 µm ± 0.9% from a homogenous mixture.

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Variation in Wood Density and Shrinkage In Two Latex Timber Clones of Rubber Trees in Different Planting Densities

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Wood density and types of shrinkage were examined in two rubberwood latex timber clones of rubber (*Hevea brasiliensis*) namely RRIM 2020 and RRIM 2025, planted at densities of 500, 1000, 1500, and 2000 trees/ha, within a trial plot. The mean wood density showed a low descending trend towards high planting densities in both clones. Wood density was significantly and negatively correlated with planting density. The strength of correlation was moderate. The mean longitudinal shrinkage in both clones and tangential shrinkages in clone RRIM 2020 showed no significant difference among planting densities. The tangential (in RRIM 2025), radial and volumetric shrinkages in both clones decreased from low to high planting densities and the differences were more pronounced between densities of 500 trees/ha and 2000 trees/ha. The magnitudes of correlation between these shrinkages and planting density were low. The regression models indicated that wood density could be more ascribed by planting density followed by volumetric shrinkage. This study exhibited low variations in wood density and shrinkages among clones and the respective planting densities; however, RRIM 2025 was more stable than RRIM 2020.

Key words: Wood physical properties; rubberwood; clonal effects; correlation; RRIM 2025; RRIM 2020

Vast areas of different clones of rubberwood (*Hevea brasiliensis*) are being planted in many parts of Asia and Africa especially in South-east of Asia owing to its fast growth rate and increasing demand for wood. Presently, rubberwood is the main plantation timber species used for the manufacture of furniture and other wood-based products. In Malaysia, the rubber tree has become the most demanded plantation species for the production of wood in downstream processes especially furniture (Teoh *et al*. 2011). Rubberwood as a tropical hardwood with indistinct growth rings is categorized as diffuse-ring porous species with the average wood densities ranging from 540 kgm^{-3} to 650 kgm^{-3}. Therefore, it is classified as medium-density timber (Hong 1996; Reghu *et al*. 2006; Norul & Sahri, 2008; Teoh *et al*. 2011). Silvicultural techniques (such as planting density) applied on plantation trees alter the growth rate and wood quality but the effect of accelerated growth on wood properties has not been fully understood (Lei *et al*. 1997). Therefore, a generalization of the effect of planting density on wood quality such as wood density, fiber characteristics, and strength properties has not been established. In addition, wood quality in every single woody species responds separately to planting density and is also affected by environmental conditions (Zobel & van Buijtenen 1989; Jiang *et al.* 2007). Zobel & van Buijtenen (1989) cited that there was no relationship between growth rate and wood density for eucalyptus; increasing wood density for *Acacia mearnsii* and adverse relationship in *Triplochiton* spp. Furthermore, adverse relationship between growth rate and wood density was also found in rubberwood by Lim and Fujiwara (1997). Therefore, as Rao *et al*. (2003) noted that recognizing the effect of growth rate on wood quality is a basic need for practicing sustainable forest management.

More often than not, wood physical properties such as wood density and wood shrinkage are widely used to determine wood quality. As far as forest products manufacturing is concerned, wood density is regarded as a highly important physical property since it has a major

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effect on yield and quality of composite and solid wood products. In the case of end products and dimensional stability, information on wood shrinkage is important and needs to be ascertained for proper evaluation of wood species. In normal wood, the longitudinal shrinkage is quite small and ranges between 0.1% and 0.3% (Shukla *et al.* 2003; Spear & Walker 2006). On the whole, the volumetric shrinkage in normal rubberwood is quite large (about 7%) and is fully related to the other dimensional shrinkages (Simpson & Wolde 1999; Bowyer *et al.* 2007).

The main objective of the present study was to determine intra- and inter-clonal variations in wood density and shrinkages in two clones of rubberwood. In addition, this study also aimed to ascertain the extent of the relationship between wood density and shrinkages with planting density.

MATERIALS AND METHODS

Study Site and Sample Selection

The study site was situated in a mini research station owned by the Malaysian Rubber Board (latitude 5◦ 45′ 0″ N and longitude of 102◦ 30′ 0″ E) in Tok Dor, Terengganu, Peninsular Malaysia. It was established in the year 2000, and was dominated by *Hevea brasiliensis* with an area of approximately 3 ha on a flat terrain. The mean annual precipitation was 3752 mm (Anon 2009). Two trial clones, RRIM 2020 (Clone I) and RRIM 2025 (Clone II) both planted at densities of 500 (PD I), 1000 (PD II), 1500 (PD III), and 2000 (PD IV) trees/ha at 9 years old were selected. Two trees from each PD were selected and felled to evaluate their physical properties. Some basic information on the mini research station features and number of test samples are presented in Table 1. Owing to the small size of the trial plot, we were not allowed to fell down more than two trees in each sampling plot. However, investigations with a similar sample size have been validated and published (Leal *et al.* 2003; Githiomi & Kariuki 2010; Uetimane & Ali 2011). The sampled trees were felled at 15 cm above ground level and the stumps were uprooted to prevent outbreak of root disease infection in the trial plots.

The modified method to describe tree (stand) growth rate named "mean radial growth increment" was used in this study (abbreviated as RGI, Table 1). It is verified as growth on a particular age at which the growth is determined (West 2006; Rodrigo 2004). Owing to indistinct growth rings in rubber trees, the mean radial annual increment was analyzed as mean DBH (diameter at breast height, cm) divided by the age of the stand (Nine years old). The mean annual increment in this study is a relative measure of the radial growth rate (Zobel 1989; Zhang 1995; Zhu *et al.* 2007).

Specimen Preparation and Testing

Wood sampling method and general requirements for physical tests were carried out in accordance to *ISO Standard 3129-1975 (E)* (Anon 1975a). The *ISO 3131-1975 (E)* (Anon 1975b) and *ISO 4469-1981 (E)* (Anon 1981) were used to measure the wood density and wood shrinkages, respectively. Since air-dry wood density (WD) can be a more practical measurement compared to the other types of wood density measurements and can provide a better understanding on how wood reacts under indoor and outdoor natural conditions, therefore in this study, the measurement of wood density was concentrated on air-dry condition.

A diametric segment of 50 mm width was cut through and through from the discs. The segments were cut into two diametric strips. The strips were used for determination of wood density and wood shrinkages. The strip was cut continuously with no interval between blocks. Due to a small DBH of the sampled trees and in order to have more sampled blocks and increase test accuracy, the dimensions of blocks were modified to 15 × 15 × 15 mm. WD was calculated according to the air-dry weights/the corresponding volumes. The air-dry volume was determined

Table 1. Basic plantation features and number of test specimens.

Clone	Pd (m)	PD	DBH	HT	N	RGI
I	4.0 × 5.0	500	20.22 a	13.2	48	22.5
	4.0 × 2.5	1000	19.19 a, b	17.2	36	21.3
	3.0 × 2.2	1500	17.43 b	17.6	36	19.4
	2.0 × 2.5	2000	17.54 b	19.8	36	19.5
II	4.0 × 5.0	500	19.96 a	14.9	48	22.2
	4.0 × 2.5	1000	16.29 b	21.0	36	18.1
	3.0 × 2.2	1500	15.27 b	22.1	36	17.0
	2.0 × 2.5	2000	15.07 b	21.6	36	16.7

Pd: Planting distance; PD: Planting density (trees/ha^{1}); DBH: Diameter at breast height; HT: Mean height of sampled trees (m); N: Number of test specimens; RGI (mm): mean radial growth increment; Means in the same column (in separate clones) followed by the same letter are not significantly different at $p < 0.05$ as determined by the Duncan's post-hoc test.

using water displacement method. For measuring wood shrinkages, after sanding all blocks, small stainless steel pins were pierced on the transverse sides. These pins with a diameter of 2 mm were used to increase the measuring accuracy, acting as centering pieces when measuring the dimensions with a dial gauge. The longitudinal, tangential, and radial dimensions of green and oven-dry specimens were measured using a digital Vernier caliper. The shrinkage was calculated by deducting the changes from green to oven-dry conditions of the blocks in the targeted side and stated as a percentage of the green volume. All blocks were appropriately marked and wrapped in dark plastic bags for further measurements.

Data Analysis

Variations in WD and shrinkage properties were evaluated using the Predictive Analytics Software (PASW) for Windows. The data was subjected to the one-way analysis of variance (ANOVA) followed by Duncan's post-hoc test to examine the differences in WD and shrinkage properties between PDs of each clone [(Duncan Multiple Range Test; DMRT) at the chosen confidence level of 95%]. Independent sample *t*-test was carried out to detect differences among two identical PDs of Clone I and Clone II ($p < 0.05$). The normality of collective data was tested for Skewness, Kolmogorov-Simrnov and Shapiro-Wilk (Ho 2006). Pearson's correlation was calculated to explore relationships between wood properties and planting density. Furthermore, simple linear regression equations were established to predict wood quality using planting density as predictor variables. The established models were evaluated based on the coefficient of determination (R^2) and significant levels. Correlation is concerned with the magnitude and direction of the relationship and regression focuses on using the relationship for prediction. Guilford's Rule of Thumb (1956) was used to describe the magnitude of correlations ($r<0.2$: negligible relationship; $r = 0.2 – 0.4$: low relationship; $r = 0.4 – 0.7$: moderate relationship; $r = 0.7 – 0.9$: high relationship; and $r >0.9$: very high relationship).

RESULTS AND DISCUSSION

Intra-clonal Variation in Wood Density and Shrinkages

The box-plots of WD vs. PD for Clones I and II show the separate trend in each clone (Figure 1). Further, the value of WD in each PD can be easily compared with the same value of the next clone (differentiated by colour). The low PD generally shows higher WD with decreasing pattern towards high PD. The WD from PD I compared to PD IV in both clones showed an increase of 9.3% and 23.1%, respectively. This is in the line with expectations since Bowyer *et al*. (2007) highlighted that growth rate (in this study planting density) may show a positive relationship with wood density. On the other hand, Jagels (2006) stated minor influence of growth rate on wood properties of diffuse-porous trees compared to ring-porous trees. However, effect of internal stresses could be developed by rapid growth.

The results of Lim and Fujiwara (1997) on a six-year-old rubberwood were contrary to the results of the present study. The possible explanation that can be ascribed to the anatomical features in the respective PDs is the positive relationship between fiber length and wall thickness with wood density as has been documented in various reports (Zobel & van Buijtenen 1989; Walker 2006; Bowyer *et al*. 2007).

Subsequent analysis in Clone I revealed significant difference only between PD I and PD II ($p < 0.05$). In clone II, the difference between PD I and the rest was significant ($p < 0.05$).

Wood shrinkage is usually judged as a function of wood density if wood density contributes a linear and high magnitude of correlation (about 90%) with planting density (Zhu *et al.* 2007). In addition, since the correlations between volumetric shrinkage and density are not constant within stems from bottom up and from pith to bark and the effects of wood density are different for tangential and radial shrinkages, wood density could be a rough indicator (Yamashita *et al.* 2009). Consequently, based on the magnitude of WD-PD correlation, it appears that WD in this study cannot be considered as a reliable parameter to judge shrinkage variations. Therefore, the correlations of wood shrinkages were established directly by PD.

Pearson's correlation coefficients indicated that WD was significantly and negatively correlated with PD ($p <0.05$). In other words, at lower PD the trees tended to have a higher WD (Table 2). The magnitude of the relationship based on Guilford's rule was categorized as moderate. Similar results were reported in *Eucalyptus globulus* (Quilhó & Pereira 2001); black spruce and red pine (Zhu *et al.* 2007).

About 34% and 43% of total variations in WD could be explained by PD (Models 1 and 6, Table 2). Therefore, WD in Clone II was more affected by the PD than Clone I. In accordance with the generalization made by Zobel and van Buijtenen (1989), the initial planting density usually used in practice has only a small effect on wood density. In spite of exceptions to this generalization was made by Lei *et al.* (1997) on alder; Fang (2003) and Jiang *et al*. (2007) on poplar, the results of the present study were consistent with that of Zobel and Buijtenen (1989).

There were small within-PD differences in longitudinal shrinkage, but were not significant in both clones (Figure 2, $p \geq 0.05$). The values of longitudinal shrinkages were in a very close range in both clones, thus changes between

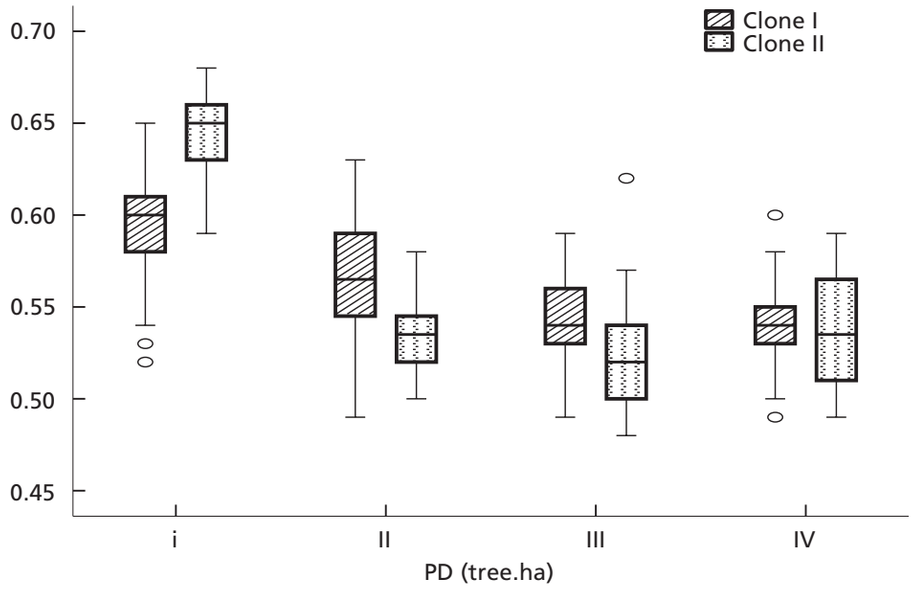

Figure 1. Box-plot of wood density in clones I and II measured at DBH in the four PDs
[Notes: a box represents the interquartile range; a line across the box indicates the median; bars (whiskers) extend from the box to the highest and lowest values; outliers (circle) are illustrated as well].

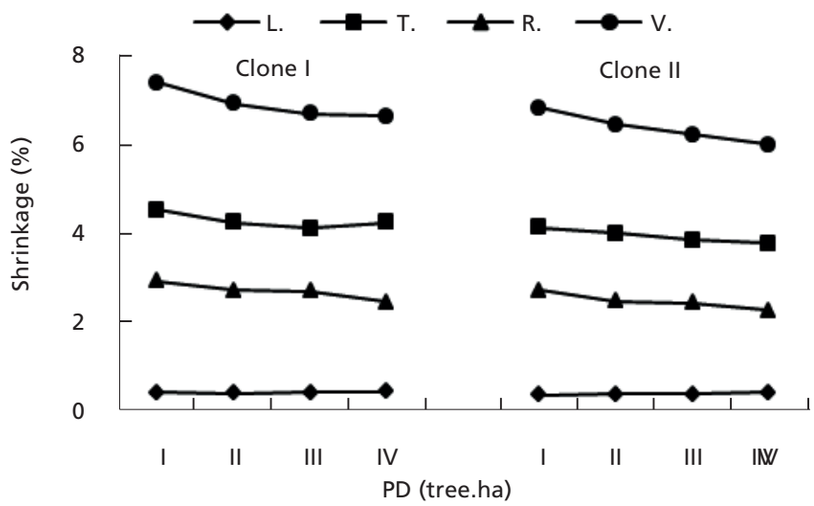

Figure 2. Trends in longitudinal (L), tangential (T), radial (R), and volumetric (V) shrinkages in the four planting densities (I, II, III, IV) of clones I and II.

Table 2. Fitted regression equations for wood density and shrinkages (y) as a function of planting density in the two clones.

Clone	Model	D.V(y)†	Regression equation	r	R2	p
I	1	W.D.	0.61 – 0.02 (PD)	–0.582	0.338	< 0.05
	2	L.S.	N.A	N.A	N.S	**0.42**
	3	T.S.	N.A	N.A	N.S	**0.14**
	4	R.S.	3.03 – 0.14 (PD)	–0.244	0.059	< 0.05
	5	V.S.	7.55 – 0.25 (PD)	–0.261	0.068	< 0.05
II	6	W.D.	0.64 – 0.03 (PD)	–0.659	0.434	< 0.05
	7	L.S.	N.A	N.A	N.S	**0.35**
	8	T.S.	4.24 - 0.13 (PD)	–0.205	0.042	< 0.05
	9	R.S.	2.80 – 0.14 (PD)	–0.310	0.096	< 0.05
	10	V.S.	7.04 – 0.27 (PD)	–0.379	0.144	< 0.05

Note: Only the significant relationships are shown ($p < 0.05$). Bold type indicates non-significant differences at the 0.05 probability level. †D.V.: Dependent variable; W.D. = Air-dry wood density; L.S. = Longitudinal shrinkage; T.S. = Tangential shrinkage; R.S. = Radial shrinkage; V.S. = Volumetric shrinkage; N.A. = Not applicable; N.S. = Not significant.

PDs were not pronounced. Regression analysis established by longitudinal shrinkage (dependent variable) and PD (independent variable) showed no significant correlation between them (Table 2).

Despite a decreasing trend in tangential shrinkage from low to high PDs (Figure 2), ANOVA test showed no significant differences between PDs in Clone I and, comparatively in Clone II, the significant difference was only between PD I and PD IV at the 95% confidence level. Consequently, the regression analysis employed for clone II was negatively and significantly correlated with planting density with r = –0.205 indicating a low magnitude of relationship. In Model 8, the R^2 showed that only 4.2% of the variation in tangential shrinkage was explained by the PD (Table 2). Therefore, the effect of initial planting density may not be distinct when the trees are young, because less competition may be expected in the trees.

The means radial shrinkages followed a descending trend from low to high PDs (Figure 2). The magnitude of the means of radial shrinkages between the highest and the lowest corresponding to the respective PDs of the two clones were 16.26% and 16.70%. The statistical analyses of the data in Clone I showed significant difference only between PD I and PD IV. In Clone II, the significant difference was between PD I and the other three PDs ($p < 0.05$). The radial shrinkage values were within the range of 2.24% – 2.89%. This range is close to the average radial shrinkage of rubberwood i.e. 2.30% (Simpson & Wolde, 1999).

The PD-radial shrinkages in both clones showed a negative significant correlation with r = –0.244 and r = –0.310, respectively. The magnitudes of the relationship were also classified as low. Based on the Models 4 and 9 presented, the examination of R^2 in radial shrinkage indicated that 5.9% and 9.6% of changes in both clones were explained by PD (Table 2).

The results showed a significant and negative correlation of PD-volumetric shrinkage. The magnitude of relationship was low. Similarly, the volumetric shrinkages in the two clones were affected by PD as indicated in Models 5 and 10, where 6.8% and 14.4% of the variations were accounted for by the PD (Table 2).

Generally, it was found that low planting density bearing high wood density represents high tangential and radial shrinkage. Similar results were reported by Wong (2002) and Alfred (2007) on Hevea and Acacia. The radial shrinkage was smaller than the tangential shrinkage. The lower shrinkage value is attributed to the presence of ray cells in radial direction and presence of lower and higher densities of wood that act in series (implications of "ray tissue" and "early wood and late wood interaction" theories). Both the dense and the light wood shrink separately and the total shrinkage corresponds approximately to the weighted mean shrinkage of the two parts (Dumail & Castera 1997; Shukla *et al*. 2003; Spear & Walker 2006).

The mean volumetric shrinkages indicate a descending trend from low to high PDs. Concerning the variation from low to high PDs, the gradient of volumetric shrinkage was found to decrease by 11.45% and 12.17% in the two clones. As expected, shrinkage demonstrated a high correlation with wood density and was greater for denser wood, which suggests that the major determinant is the amount of wood substance in unit area (Dumail & Castera 1997; Alfred 2007). The volumetric shrinkage from green to oven-dry state in Clone I was not significantly different between PD I and PD II and also between PDs II, III, and IV. In Clone II, the volumetric shrinkage showed significant differences between PD I vs. PDs II, III, and IV; and PD II vs. PD IV. The differences between PD II and PD III and between PD III and PD IV were not significant. The results on correlations indicate that the changes in the longitudinal shrinkage will not affect the volumetric shrinkages (Table 2).

The changes in volumetric shrinkages are strongly related to tangential and radial shrinkages. In general, the relationships between the different PDs and shrinkage properties were rather weak or non-significant.

The values of shrinkages from the present study and some data on tropical hardwoods are presented for comparison (Table 3). The information indicates that volumetric shrinkage values of rubberwood were either comparable or smaller than most popular tropical hardwoods.

In addition, the differential shrinkage ratio (tangential upon radial: T/R) of rubberwood in the present study was relatively small compared to other common hardwoods. This suggests the dimensional stability of rubberwood with a wider range of utilization. However, the utilization options of new silviculturally-managed rubberwood needs in depth study.

Inter-clonal Variation

The results of the independent *t*-test of mean WD and shrinkages showed that the differences values (increase/reduction) among the identical planting densities were insignificant and negligible (>10%). Therefore, it could be suggested that the WD and shrinkages in both clones were similarly influenced by initial planting density (Table 4).

Table 3. Radial, tangential and volumetric shrinkages of some tropical hardwoods. †

Species	Radial	Tangential	Volumetric	T/R
*Hevea brasiliensis**	2.24 – 2.89	3.75 – 4.51	5.99 – 7.40	1.67 – 1.56
Hevea brasiliensis	2.3	5.1	7.4	2.22
Shorea spp.	3.4	8.0	10.4	2.35
Acacia hybrid (NSPG, 11 yrs)	2.9	5.3	9.1	1.83
Tectona grandis	2.3	4.8	6.8	2.09
*Azadirachta excels***	3.8	6.1	9.6	1.61

† Adapted from Simpson and Wolde (1999) and Alfred (2007); *Present study; The age of some species mentioned in the table were undefined; NSPG: Non-stressed plantation grown; ** Seedling. yrs: years.

Table 4. Independent samples *t*-test comparing the air-dry wood density and shrinkages in the same planting densities of the two clones.

Feature †	PD	Red./Inc. (%)	Sig.
W.D.	A_I-B_I	8.47	< 0.05
	A_{II}-B_{II}	–5.56	< 0.05
	A_{III}-B_{III}	–3.70	< 0.05
	A_{IV}-B_{IV}	N.A	0.96
L.S.	A_I-B_I	N.A	0.39
	A_{II}-B_{II}	N.A	0.74
	A_{III}-B_{III}	N.A	0.36
	A_{IV}-B_{IV}	N.A	0.60
T.S.	A_I-B_I	N.A	0.10
	A_{II}-B_{II}	N.A	0.19
	A_{III}-B_{III}	N.A	0.10
	A_{IV}-B_{IV}	12.5	< 0.05
R.S.	A_I-B_I	N.A	0.11
	A_{II}-B_{II}	N.A	0.11
	A_{III}-B_{III}	N.A	0.06
	A_{IV}-B_{IV}	N.A	0.17
V.S.	A_I-B_I	8.0	< 0.05
	A_{II}-B_{II}	7.1	< 0.05
	A_{III}-B_{III}	6.9	< 0.05
	A_{IV}-B_{IV}	9.8	< 0.05

Note: Bold type indicates insignificant difference at the 0.05 probability level. A ($_{I, II, III, IV}$) = Planting density number I, II, III, and IV in clone RRIM 2020. B ($_{I, II, III, IV}$) = Planting density number I, II, III, and IV in clone II. † W.D.: Air-dry wood density; PD = Planting density. L.S.: Longitudinal shrinkage; T.S.: Tangential shrinkage; R.S.: Radial shrinkage; V.S.: Volumetric shrinkage. Red. /Inc = Reduction/Increase: Comparison of the percentage of reduction or increase of a certain feature value in the identical PDs of the two clones. The signs +/_ show direction of value's increase or reduction in Clone I versus Clone II. N.A.= Not applicable.

Large variation in wood density among trees is not unusual for diffuse-ring porous species (Gartner *et al.* 1997). The clonal variability in wood properties may create genetic selection for desirable characteristics feasible. PD I in both clones showed best performance in wood density between the clones. Meanwhile, the results demonstrated that PD I of Clone II was the best among the two clones (Table 4).

CONCLUSION

The WD was influenced by PD. A descending trend from low to high PDs was revealed in both clones. Within each clone, PD I showed the highest values of WD and therefore, PD I of Clone II was pronounced the best predictor of this feature.

The longitudinal shrinkages in both clones were not significantly affected by PD. The tangential and radial shrinkages were moderate, while volumetric shrinkage was highly influenced by PD. The highest values of all shrinkages were in PDs I of both clones that were somehow in line with WD. The tangential shrinkage variation along the different PDs was associated with variation in PDs in both clones and that wood in low PD tends to be more shrunk than wood in high PD. PD was weakly correlated to wood shrinkages. In general, it can be concluded that clone RRIM 2025 emerged as a better clone due to more stable wood properties.

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Classification of Chlorophyll-*a* Concentrations in Surface Waters of Songsong Group of Islands Using an Optically Derived Remote Sensing Model

A.L. Abdullah[1]*, H.S. Lim[2], Z. Yasin[3] and N.M. Razalli[3]

Chlorophyll-*a* concentrations (mg/l) in surface waters of Songsong Islands were mapped using an optically derived remote sensing model. Landsat TM imagery dated 8 October 2008 was used in the classification process and *in situ* measurements made on 19 May 2012 during spring tidal condition (HW: 2.6 m, LW: 0.9 m) served as ground truthing data. The temporal difference between data used will be useful to review the robustness of the model. Three classes of chlorophyll-*a* concentrations were mapped: Class 1: <6 mg/l; Class 2: 6 mg/l–10 mg/l, and Class 3: >10 mg/l. Considering the dynamic nature of coastal and marine waters particularly the shallow region, and the temporal difference between the Landsat TM imagery used in classification and the field data, results of chlorophyll-*a* mapping using the developed remote sensing model was high at 83.3%, with producer's accuracy of 50%–100% and user's accuracy of 80%–100%. Kappa coefficient of agreement, $\hat{K}$, calculated was 57.1%.

Key words: Chlorophyll-*a*, optical chlorophyll model; turbid water; fringing reef; Straits of Malacca; Landsat TM imagery

An important parameter in evaluating water quality, nutrition status and organic pollution extent is the chlorophyll-*a* (Chl-*a*) concentration. Chl-*a* is the pigment that participates directly in the light requiring reactions of photosynthesis. Its concentration provides useful information for the management of water quality (Scherz 1972) and the monitoring of water pollution (Johnson & Harris 1980). The coastal water is dynamic in nature, consequently Chl-*a* concentration changes rapidly and continuously. The spatial distribution of Chl-*a* in coastal seawater is not homogeneous either. Charting of Chl-*a* concentrations spatially over large areas through remote sensing can provide an alternative synoptic view, speedy and cost-effective method compared to the lengthy and expensive conventional practice (Curran & Wilkinson 1985; Abdullah 2004). Great deal of research has been carried out for the measurement and building of Chl-*a* concentration models using remote sensing data such as Landsat MSS, Landsat TM, SPOT, IRS-1C and SeaWiFS (Dekker & Peters 1993; O'Reilly *et al.* 1998; Thiemann & Kaufmann 2000; Hanna *et al.* 2001; Harding *et al.* 2005). Chl-*a* concentration models can be built theoretically (Hoogenboom *et al.* 1998; Carder *et al.* 1999; Bricaud *et al.* 1990), empirically or semi-empirically (Dekker & Peters 1993; Gitelson 1992; Han & Rundquist 1997; Rundquist *et al.* 1995), optically (Lim *et al.* 2009; Beh *et al.* 2010; Asadpour *et al.* 2011) or based on artificial neural network method (Keiner & Yan 1998) and genetic algorithm (Doerffer & Fischer 1994). The origin of this study was based on Chl-*a* concentration, being a good indicator for the possibility of nutrient loading or organic pollution and the productivity status of reefs in particular, and the application of optically-derived remote sensing model.

The Study Area

This study aimed at Pulau Songsong, Pulau Bidan, Pulau Telor and Pulau Bunting as the study area. These islands commonly referred to as Songsong group of islands are coastal islands belonging to the State of Kedah. The islands are located in the northern region of Straits of Malacca

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(Figure 1). Amongst these four, Pulau Bunting is the only human inhabited island. The unpopulated islands used to be target shooting zone to the Royal Malaysian Air Force which has now ceased operation. Pulau Songsong, Pulau Bidan and Pulau Telor are surrounded with shallow and narrow fringing reefs. These reefs, though have deteriorated over the decades, were fragmented but still intact despite the continuous pressure of target shootings. Due to their proximity to northern coast of mainland peninsular, the waters around this region has the tendency to be turbid with high suspended sediment (Abdullah & Yasin 2000) and a recipient of influx of other anthropogenic influences.

The Study Objectives

In our efforts to enhance scientific knowledge of marine biodiversity for the purpose of conservation and sustainable management in coastal and marine zones with turbid waters, not only do we measure or catalogue the living resources, factors affecting the very existence and the survival of these resources ultimately entailed. In this study, the water quality parameters measured were Chl-*a* concentrations and its associated subsidiary chemical parameters i.e. nitrite, nitrate ammonia and ortho-phosphate concentrations. The objectives were: (1) To map the distribution of Chl-*a* concentration of coastal and marine surface waters of Songsong Group of Islands using an optically derived remote sensing model; and (2) To review the robustness of the model. The intent of mapping of Chl-*a* concentration distribution was to prove three hypothesis: (1) The shallow coastal waters along the study area has higher level of Chl-*a* concentrations; (2) The level of Chl-*a* concentrations are probably related to nutrient inputs from runoffs of adjacent coastal agricultural land; and (3) The existing narrow shallow reefs do still show acceptably high productivity level.

MATERIALS AND METHODS

Chl-*a* concentrations and its associated water quality parameters (nitrite, nitrate, ammonia and ortho-phosphate) were measured at 12 stations in the surface waters of Pulau Songsong, Pulau Bidan and Pulau Telor (Figure 2). Measurements were taken on 19 May 2012 during spring tidal condition (HW: 2.6 m, LW: 0.9 m).

In the image processing phase, corrected Landsat TM subset imagery (date: 8 October 2008) of the study area was classified using an optically derived model for surface water Chl-*a* concentrations in mg/l (Lim *et al.* 2009) through PCI Geomatica *ver*. 10.1. The R_1 in the model used represents the red band of EMR.

$$\text{Chlorophyll-}a\text{ Model: CHL} = (-0.0411)R_1^2 + 7.5288R_1 + 327.1 \quad (1)$$

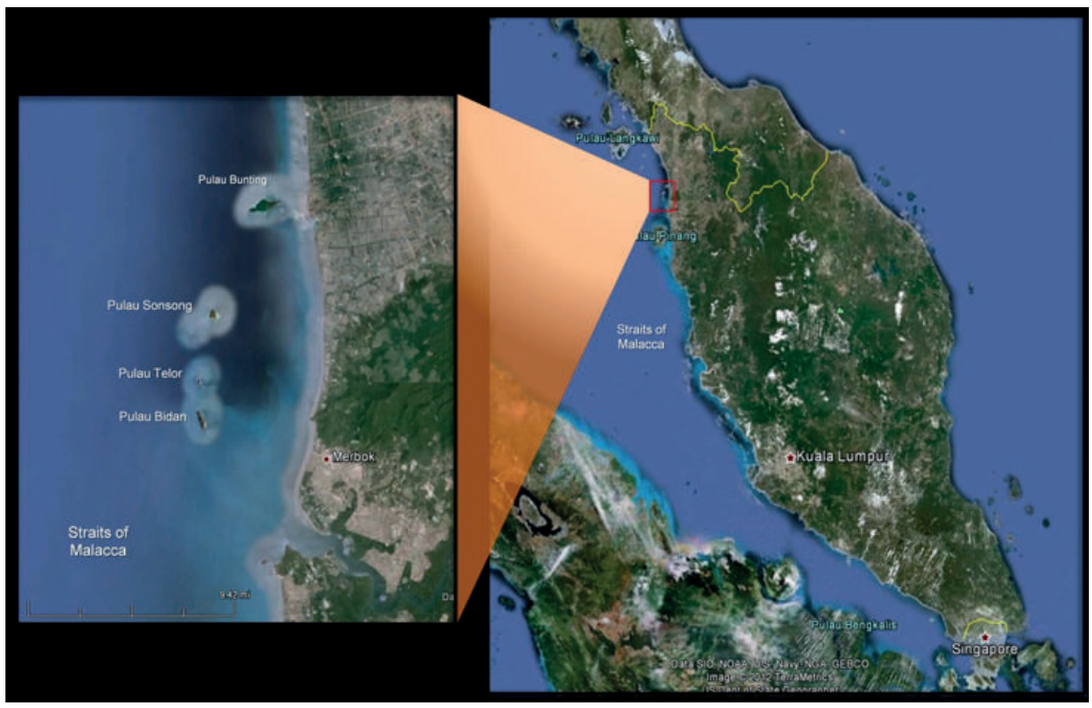
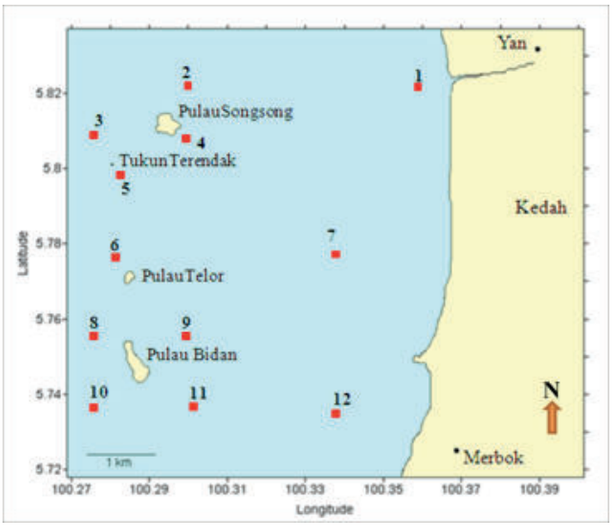


Figure 1. The study area: Coastal and marine waters of Songsong Group of Islands, Northern Straits of Malacca.



Station	Latitude	Longitude
1	5.8191	100.3587
2	5.8321	100.3000
3	5.8044	100.2596
4	5.8061	100.2988
5	5.7998	100.2792
6	5.7798	100.2801
7	5.7799	100.3399
8	5.7545	100.2600
9	5.7552	100.3003
10	5.7298	100.2600
11	5.7303	100.2999
12	5.7300	100.3305

Figure 2. Location of sampling stations in Pulau Songsong, Pulau Telor and Pulau Bidan.

Results of chemical parameters measured will be used as contributory datasets for Chl-*a* concentrations. In any map production, accuracy assessment is compulsory to portray how well a map actually represents what is out there. Without an accuracy assessment, a classified map is just a pretty picture. For the purpose of this study, field measurements of Chl-*a* concentrations will be employed as ground truthing data for verification and computation of accuracy assessment. Since a developed model will be used in determining Chl-*a* concentrations, evidently field measurements will serve as verification to mapping accuracies and the gauging of robustness of the optical model. An error matrix will be composed to calculate total mapping accuracy, the producer's and user's accuracies and to determine the level of commission and omission errors. $Kappa_{(hat)}$ Coefficient of Agreement will also be calculated based on the following equation:

$$K = \frac{N\sum_{i-1}^{k} x_{ii} - \sum_{i-1}^{k}(x_{i-} \chi x_{-i})}{N^2 - \sum_{i=1}^{k}(x_{i+} \chi x_{+i})} \quad (2)$$

Figure 3 outlines the overall framework of the study. There has never really been any standard classification categories for levels of accuracy where remote sensing of the dynamic coastal and marine waters is concerned. For the purpose of this study the typical grading category is employed and referred to in this study (Table 1a). Interpretation of Kappa Coefficient of Agreement is provided in Table 1b).

RESULTS

Distribution of Chlorophyll-*a* Concentrations on Coastal and Marine Surface Waters

Results of the classification showed three groups of Chl-*a* concentration ranges which are Class 1: [Chl-*a*] = <6 mg/l, Class 2: [Chl-*a*] = 6–10 mg/l, and Class 3: [Chl-*a*] = >10 mg/l (Figure 4). Higher range (>10 mg/l) of Chl-*a* concentrations were clearly distributed within the shallower bathymetric region which was about 2.67 km to 6 km from the general coastlines and along fringing reefs of Pulau Songsong, Pulau Bidan, Pulau Telor and Pulau Bunting. This range of Chl-*a* concentrations, however, extended further into the sea from the river mouth of Sungai Muda as far as 11.63 km. It was observed in the map that the eastern tip of Pulau Bunting was exposed to the higher range of Chl-*a* concentration.

In situ Chlorophyll-*a* Concentrations and Associated Water Quality Parameters Measured

Mean Chl-*a* concentrations (mg/l) measured in the 12 sampling stations ranged from 5.960 ± 0.634 mg/l to 16.875 ± 3.826 mg/l. The range of nitrite (NO_2) concentrations was 0.001 ± 0.003 mg/l to 0.037 ± 0.029 mg/l; nitrate (NO_3) concentrations was 0.003 ± 0.008 mg/l to 0.110 ± 0.087 mg/L; ammonia (NH_4) concentrations was 0.005 ± 0.004 mg/l to 0.176 ± 0.023 mg/l; and ortho-phosphate (ortho-PO_4) concentrations was 0.045 ± 0.013 mg/l to 0.387 ± 0.023 mg/l. These measurements were charted in Figures 5 and 6. From the general trends, the highs and

Table 1a. Typical grading category employed for remote sensing classification of coastal-marine water accuracy levels. (Table 1b) Agreement levels and values for Kappa Coefficient of Agreement interpretation.

(a) Accuracy level	Percentage
Very high	91 to100
High	80 to 90
Moderately-high	71 to 80
Moderate	61 to 70
Moderately-low	51 to 60
Low	41 to 50
Very low	≤ 40
(b) Agreement level	**Agreement value**
Very good agreement	0.80 to 1.00
Good agreement	0.60 to 0.80
Moderate agreement	0.40 to 0.60
Fair agreement	0.20 to 0.40
Poor agreement	Less than 0.20

Source: Altman (1991)

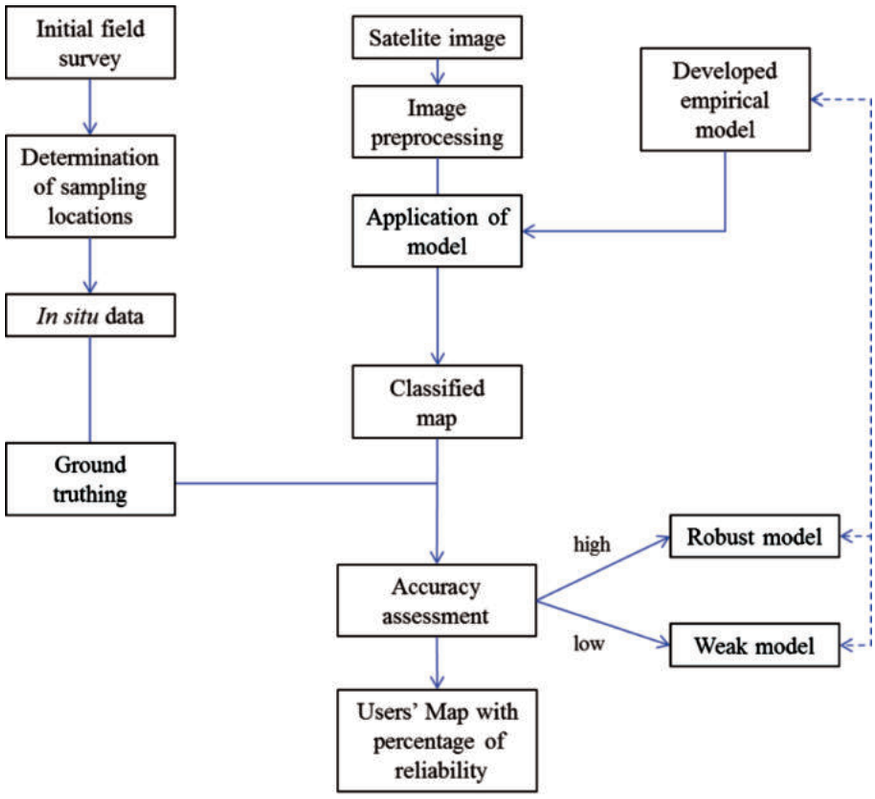


Figure 3. Methodology flowchart.

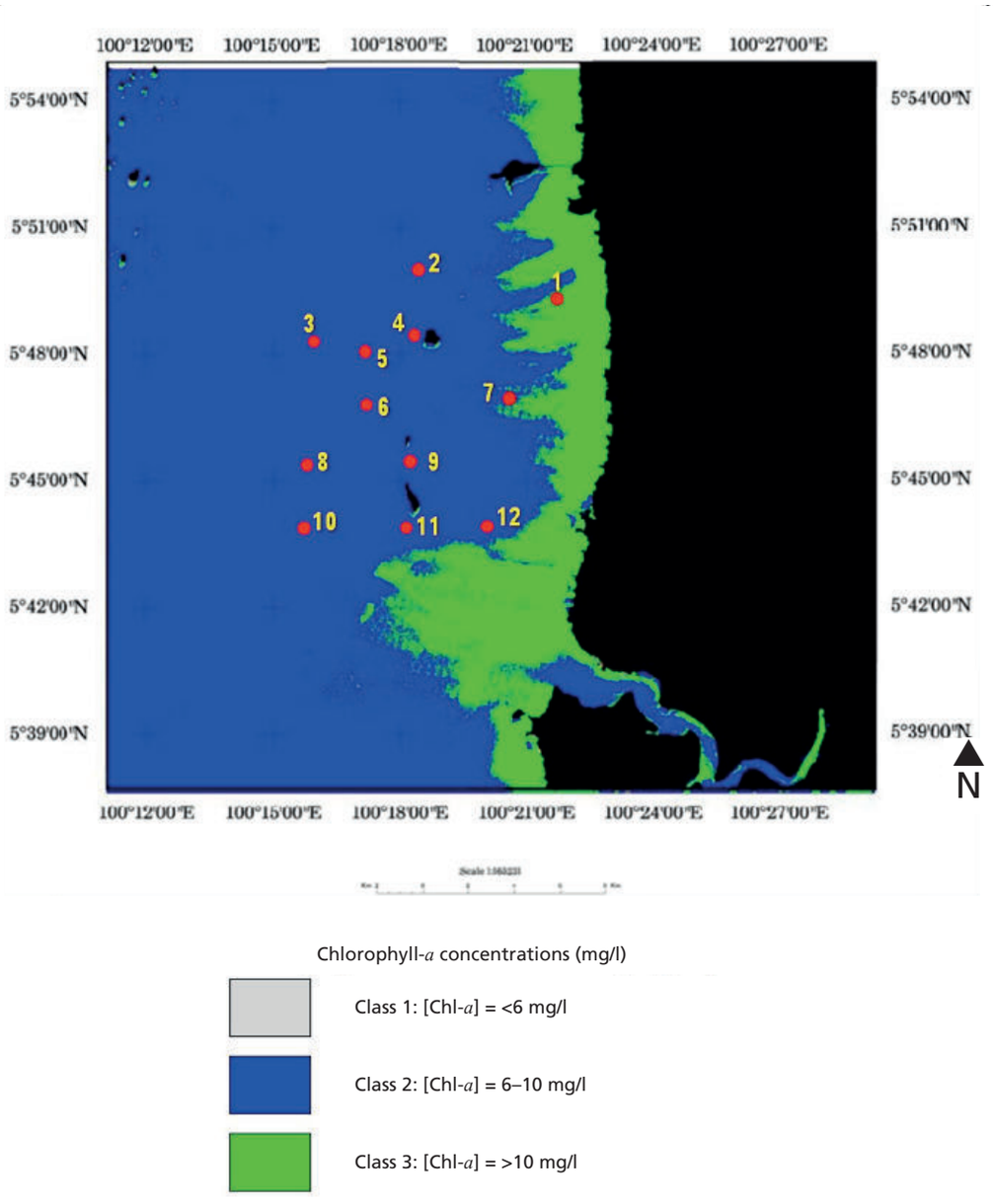


Figure 4. Distribution of Chlorophyll-*a* Concentrations in Coastal and Marine Surface Waters of Songsong Group of Islands.

lows of the mean values plotted corresponds to each other. Elevated levels of all nutrient parameters including Chl-*a* concentrations were observed at three particular stations (Stations 1, 7 and 12) which were located nearest to the coastal land.

Accuracy Assessment of Chlorophyll-*a* Concentrations: Computation of Error Matrix

Minimum and maximum range of Chl-*a* concentrations were calculated from the mean values prior to accuracy assessment process (Table 2). These measured field data and the classified data were compared through error matrix computation (Table 3). Accuracy of remote sensing classification conducted through this matrix showed overall accuracy was high at 83.3%. Producer's accuracy for [Chl-*a*] = 6–10 mg/l was 100% while for [Chl-*a*] = >10 mg/l was 50%. User's accuracy for [Chl-*a*] = 6 mg/l – 10 mg/l was 80% and [Chl-*a*] = >10 mg/l was 100%. Producer's and User's accuracies for [Chl-*a*] = <6 mg/l were not calculated although this range was detected in the remote sensing classification process. The mapped area for this range, depicted as grey tone, was minimal that it was considered insignificant. Errors of Omission (EO) and

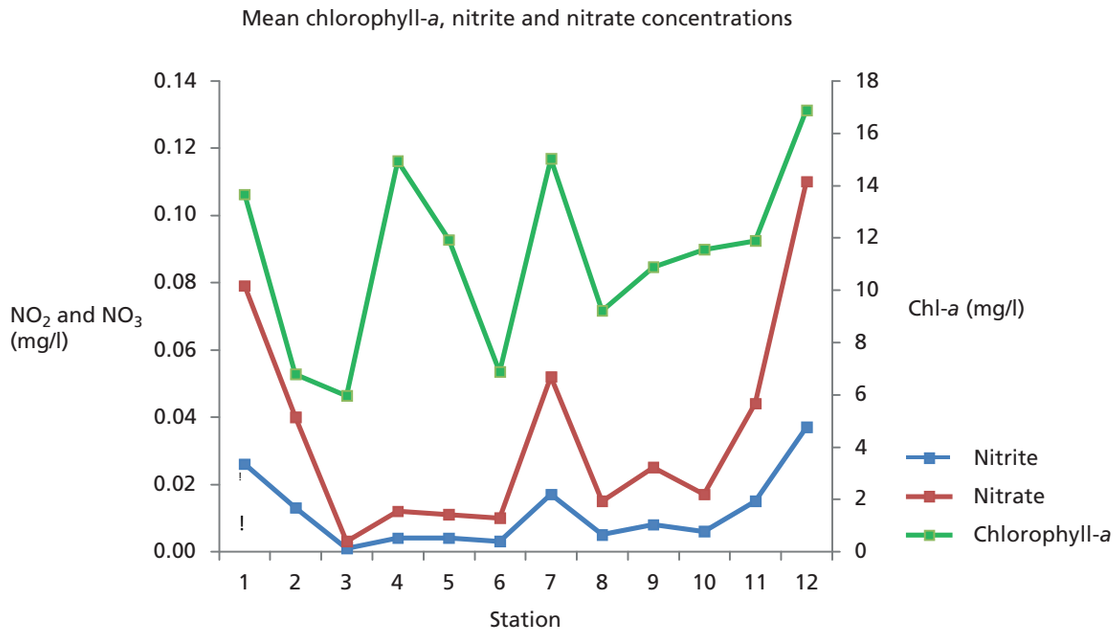


Figure 5. Mean values of nitrite and nitrate concentrations plotted as comparison to Chlorophyll-*a* concentrations in surface waters of Songsong Group of Islands.

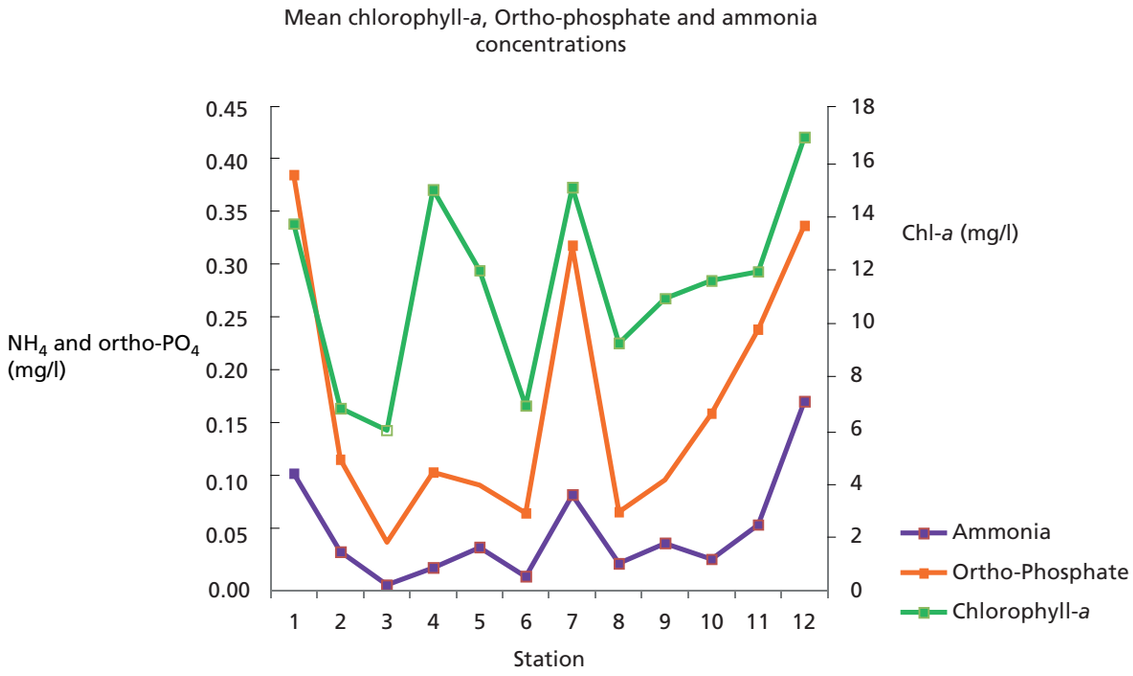


Figure 6. Mean values of ammonia and ortho-phosphate concentrations plotted as comparison to Chlorophyll-*a* concentrations in surface waters of Songsong Group of Islands.

Table 2. Minimum and maximum measured chlorophyll-*a* concentrations and classified remote sensing data of songsong Group of Islands.

Station	Mean value chlorophyll-*a* (mg/l)	Minimum chlorophyll-*a* (mg/l)	Maximum chlorophyll-*a* (mg/l)	Classified chlorophyll-*a* data	Mapping accuracy
1	13.653	10.343	16.963	> 10	√
2	6.780	4.886	8.674	6–10	√ (UL)
3	5.960	5.326	6.594	6–10	√ (UL)
4	14.928	10.806	19.050	6–10	X
5	11.918	9.329	14.507	6–10	√(LL)
6	6.875	5.238	8.512	6–10	√ (UL)
7	15.019	10.793	19.245	> 10	√
8	9.208	7.823	10.593	6–10	√ (LL)
9	10.875	9.313	12.437	6–10	√ (LL)
10	11.542	10.401	12.683	6–10	√ (LL)
11	11.875	9.662	14.088	6–10	√ (LL)
12	16.875	13.049	20.701	6–10	X

Abbreviation Note:
UL: Upper limit (higher value of field measurement)
LL: Lower limit (lower value of field measurement)

Table 3. Error matrix computation for chlorophyll-*a* concentrations in Northern Region of Straits of Malacca for accuracy assessment, and error of omission and error of commission.

		Reference data				User's accuracy (Error of commission)
	Class	1	2	3	Total	
Classified data	1	0	0	0	0	0% (0%)
	2	0	8	2	10	80% (20%)
	3	0	0	2	2	100% (0%)
	Total	0	8	4	12	
Producer's accuracy (Error of omission)		0% (0%)	100% (0%)	50% (50%)		Total accuracy: 83.3%

Kappa ($\hat{K}$) = 0.57% or 57.1%

Errors of Commission (EC) calculated were also given in Table 3. EO for Class 3 was at 50% while EC for the Class 2 was 20%. Kappa ($\hat{K}$) Coefficient of Agreement was 0.57 (57.1%), indicating a moderate agreement.

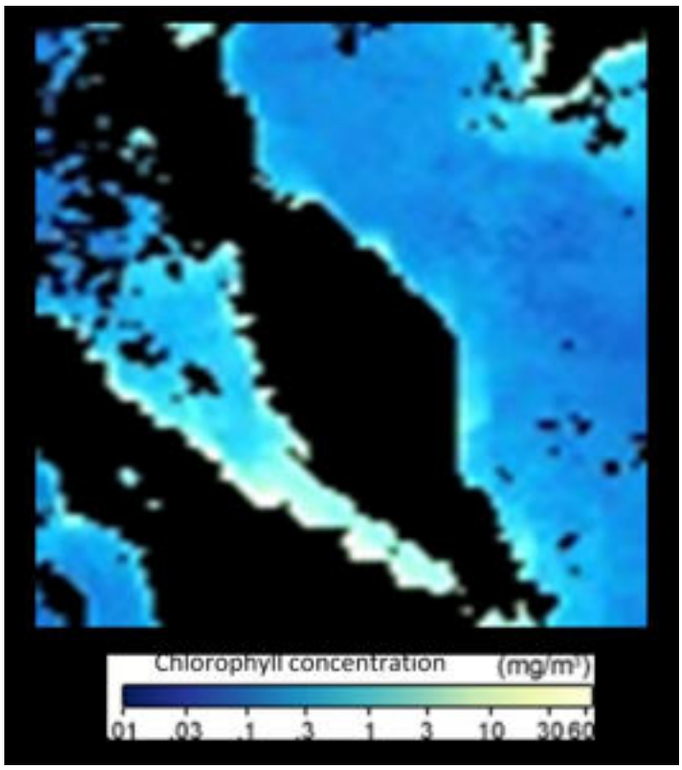
DISCUSSION

It is natural for Chl-*a* concentrations to fluctuate over time. Factors influencing these fluctuations are quite broad, for instance, Chl-*a* concentrations are often higher after rainfall, particularly if the rain has flushed nutrients into the water. Amount of light levels reaching the photic zone and the tidal regime are important controls on algal biomass. Tidal mixing and flushing rates (e.g. estuarine and river mouths) influence Chl-*a* concentrations because flushing dilutes nutrients and moves them away, making them less available (Brando *et al.* 2006). Conversely, slow moving or stagnant waters such as the case along Kedah coastline facing the Songsong Group of Islands which are shallow, let nutrients increase and cell numbers to grow. As a result, higher Chl-*a* concentrations were detected along the coastlines, and this can reflect a possible increase in nutrient loads.

Higher productivity levels mapped from the TM data along the shallow coastlines and the higher range Chl-*a* concentrations measured in the shallow waters along the coastlines of the study area proved the first hypothesis true. This zone lies along the lines of the famous rice bowl region of Peninsular Malaysia. Nutrient runoffs such as nitrogen and phosphorus from the agricultural practices

(rice cultivation) along the coastlines are highly probable. The level of nutrient inputs of nitrite, nitrate, ammonia and ortho-phosphate measured in this study with the Chl-*a* concentrations observed particularly at the three sampling stations nearest to coastal peninsular supported the second hypothesis of this study. These nutrients coupled with the shallow coastal features became sources of algal propagation in the seawater column. The area of Chl-*a* > 10 mg/l concentrations stretched from 2.67 km to 6 km from Kedah coastline with the exception of the river mouth of Sungai Muda which extended to 11.63 km from the coastline. The possible extent of nutrient flux from the coastal land did not reach the relatively deeper waters of Pulau Songsong, Pulau Bidan, and Pulau Telor (which lie at a distance of 8.08 km – 8.99 km from the coastlines), possibly owing to the pattern of water movement and the distance which shelter the reefs from the nutrient impact. Due to this possibility, the similar Chl-*a* concentrations (>10 mg/l) mapped along the narrow reef regions of the Songsong Group of Islands most likely represented the living corals within the shallow reef. The levels of Chl-*a* concentration measured concurred with findings of NASA Earth Observatory for May 2012 shown in Figure 7 (NEO 2012). The spectral signal detected in the TM data was therefore attributable to the chlorophyll pigment present in corals, a potential indication of considerably good productivity of healthier or surviving corals. This finding supported the third hypothesis of this study.

On the basis of coastal and marine water dynamics, coupled with the broad difference of time between *in situ* data and TM data used in the remote sensing image processing, the optical Chl-*a* model of (–0.0411) R_1^2 + 7.5288R1 + 327.1 is considered robust enough due to the high overall accuracy level of 83.3% achieved and may well be applicable within the waters of Straits of Malacca. Kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 imply less than perfect agreement. It is rare that we get perfect agreement. In this study the Kappa values showed a moderate agreement (0.57) which is acceptable with the 83.3% of overall mapping accuracy.The robustness of the model needs regular verification for its applicability i.e. whenever mapping of Chl-*a* concentrations is performed using the model. The rationale of this was the high correlation between Chl-*a* concentrations and turbidity levels in the coastal and marine waters (Abdullah & Yasin 2000; Ritchie *et al.* 2003; Abdullah 2004). Earlier studies by Dekker and Peters (1993) and Ritchie *et al*. (1994) too documented that while estimating chlorophyll



Source: NEO (2012)

Figure 7. Chlorophyll concentration (mg/l) (Aqua/MODIS) for May 2012.

using remote sensing techniques is possible, other studies have also shown that the broad wavelength spectral data available on most current satellites do not permit discrimination of chlorophylls in waters having high suspended sediments due to the dominance of the spectral signal from the suspended sediments. *In situ* data collected for this study and from previous studies by Abdullah and Yasin (2000) and Abdullah (2004) showed a broad range of suspended sediment ranging to a maximum of 250 mg/l in the northern waters of Straits of Malacca. As indicated by Abdullah (2004), sensitivity of the models vary depending on the basis of model building. Some models, for instance, were designed for lower range sensitivity although it can detect higher range. The factor in question then is the level of mapping accuracy. On this footing, it is factual to state that the optical Chl-*a* model employed in this study is robust and yield considerably good mapping accuracy in suspended sediment-laden waters with a maximum 250 mg/l suspended sediment concentration.

Another important point to be indicated in this study was there are advantages of measuring Chl-*a* over nutrient concentrations, although measurement of nutrients are still necessary as subsidiary dataset. These advantages are:

(1) *Integration over time*: Phytoplankton assimilate available nutrients over their lifetime, whereas water column inorganic nutrient concentrations are notoriously variable over much shorter time scales.
(2) *Sensitivity*: Phytoplankton respond rapidly to pulsed nutrient inputs that might otherwise go undetected by regular nutrient sampling.
(3) *Ease of collection*: Chl-*a* samples require minimal processing and storage in the field and are not easily contaminated.
(4) *Cost*: Chl-*a* is cheap in comparison to the analysis of a full suite of dissolved nutrients.
(5) *Detectability*: Remote sensing can detect chlorophyll concentrations but cannot detect nutrient concentrations such as phosphorous and nitrogen directly.

In the era of sustainability as we are now experiencing, we are compelled towards inventory of the existence of surviving living resources, the reef organisms. Researchers and environmental managers exhilarate upon findings with a long list of surviving marine biodiversity regardless of their population sizes. However, we cannot shelve the conception of continuous monitoring of reef environment that in long term threatens the very existence of these marine biodiversity. Since application of remote sensing in large area is very viable and useful, for that reason water quality management and water pollution monitoring using this technique on regular basis should be mandatory for natural heritage resource management such as our marine park management, conservation and sustainability efforts.

CONCLUSION

Considering the dynamic nature of coastal and marine waters particularly the shallow region, and the 4-year temporal difference between the Landsat TM imagery used in classification and the field data, results of chlorophyll-*a* mapping using the developed model was high at 83.3% with $\hat{K} = 0.57$. With the increasing pressure globally in efforts to decrease human impacts on our living resources leading to the quest to enhance scientific knowledge of marine biodiversity for the purpose of conservation and sustainable management, methods of rapid data gathering have resorted to the use of cost-effective data and application of remote sensing technology. This study has proven the possibility to measure factors affecting the existence and the survival of living resources in large scale. Effects of exposure period of living organisms to pollutants could be monitored and predicted to gauge overall vitality of reefs and the sustainability of physical environment. These are large scale tools in ensuring continuous pool of coastal and marine biodiversity to secure survival of living organisms and their key roles in the web of life which humanity thrive on.

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Health Related Quality of Life Using Commercially Prepared Food Supplements, Multivitamins and Minerals — A Meta-Analysis

R.(III) P. Dioso

Through the six domains of the health-related quality of life (HRQOL) — physical, psychological, level of independence, social relationship, environment and spirituality or religion — ten out of one hundred randomly selected studies were analysed and evaluated as a theoretical outcome of self care using health products such as food supplements, multivitamins and minerals.

A reconstructed HRQOL tool was used in the qualitative and the quantitative analysis and evaluation of the ten selected studies. A Critical Appraisal Skills Programme tool was also used in making sense of the evidences of the study trials. The Population, Intervention, Comparison and Outcome guide focused the protocol for the selection of the studies used in this meta-analysis. A probability sampling generated a uniform distribution of the populations. The manner of consuming or the route of administration, the volume and the preparation of commercially prepared health products were neither analysed nor evaluated as the exclusion criteria.

Of the ten studies, nine gave a high significance to the six domains of the (O.R. = 90% / p = <0.05). The six domains of the HRQOL showed a significant relationship to the extrinsic factors — age, gender, health status, location of residency and ethnicity/genetic.

Key words: HRQOL; self care; health products; qualitative and quantitative meta-analysis

Multivitamins, minerals and food supplements are used as health products all over the world — for children with Rickets in Nigeria (Thacher *et al.* 1999), for human immunodeficiency virus patients in Tanzania (Fawzi *et al*. 2004), for health conscious adults in United States of America (Radimer *et al*. 2004), and for athletes in Norway (Sundgot-Borgen *et al*. 2003) and in the United Kingdom (Nieper 2005); for health promotion and illness prevention in Malaysia (Aziz & Tev 2009), and for patients with cancer and cardiovascular disease in China (Blot *et al*. 1993) and Japan (Ishihara *et al*. 2003). Health products cater to these populations' individual needs to achieve a qualitative life.

This study aims to evaluate self care (Orem 1991) using health products in achieving the six domains of the Health Related Quality of Life (HRQOL) — physical, psychological, level of independence, social, environmental and spiritual/religion.

According to the World Health Organization (WHO) (2004), the six domains of the HRQOL are somehow affected by five extrinsic factors — age and location of residency, gender, health status and ethnicity/genetics — contributing to the usage of commercially prepared multivitamins, minerals and food supplements.

On account of these issues, this study also aims to analyse the HRQOL's six domains affected by the five extrinsic factors.

The purpose of this meta-analysis study is to promote the *Self Care Theory* (Orem 1991), beneficial for health that analyses and evaluates quality of life (QOL) (WHO 2003/2010). According to Orem (1991), self-care is to initiate time frames of lives in one's own behalve based on specific needs.

A Venn diagram is best used to illustrate the variables and their logical relations to achieve a significant HRQOL (Figure 1). To explain further, gender, health status, age, location of residency and ethnicity/genetic factors are the reasons behind the use food supplements, multivitamins and minerals as a demonstration of self care that can

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achieve the six domains of the HRQOL — the qualitative and quantitative paradigm of this study.

The PICO (population, intervention, compariaon and outcome) guide helped in the formulation of a focused question stating: Do multivitamins, minerals and food supplements achieve a significant HRQOL? The focused question, as a chain reaction, leads to the formulation of a hypothesis stating that the six domains of the HRQOL significantly demonstrate self care (Orem 1991) by using food supplements, multivitamins and minerals. Another formulated hypothesis is the evaluation and analysis of the significant relationship of the five extrinsic factors affecting the HRQOL.

These hypotheses contributed to the method of selecting research studies on HRQOLs.

SEARCH STRATEGY

The PICO guide also was used to focus the search with key words as texts entered on databases. The databases were *CINAHL* (Commulative Index for Allied Health Literatures) (1000 studies), Proquest (5000 studies) and *ResearchGate* (10 500 studies).

The PICO guide are enumerated as: adults and children using food supplements (population) as text words entered on Proquest*;* usage of health products and food supplements (intervention and comparison) as in-texts entered on *CINAHL*; and health related quality of life using food supplements, vitamins and minerals (outcome) as text words entered on *ResearchGate*.

Of the one hundred studies found on databases only ten were selected that spanned from years 2000 to 2013 using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline by Moher *et al.* (2009) found on Figure 2.

METHODS

The methods of controlling biases include the inclusion and exclusion criteria. Independent reviewers must note

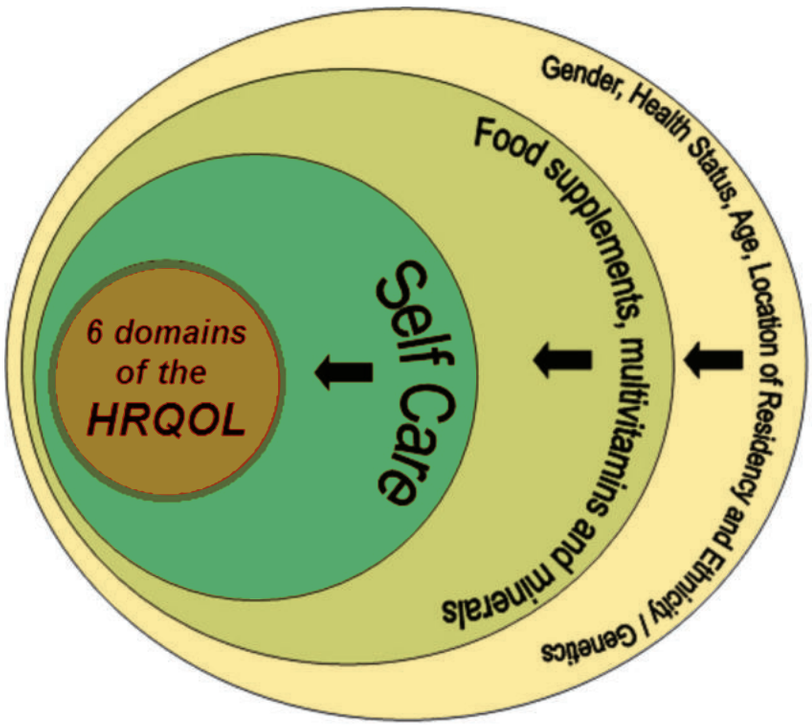

Figure 1. The paradigm used in this meta-analysis in a Venn diagram.

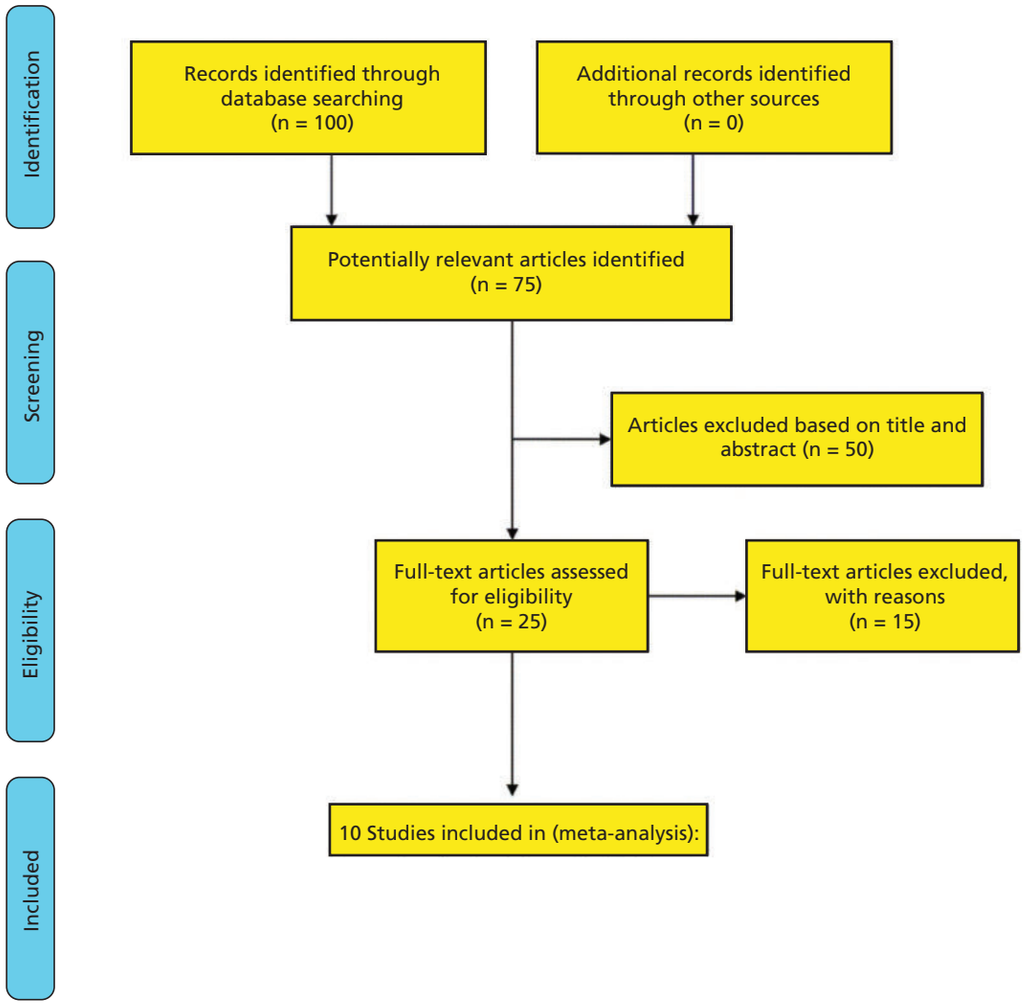

Figure 2. Search protocol.

that the manner of preparation, the manner of consuming or the route of administration and the volume of the multivitamins, minerals and food supplements are not analysed and evaluated. Only the focused question and focused population are measured if it achieves a significant HRQOL. Focused populations were categorised as pregnant women, normal toddlers, children with attention deficit hyperactive disorders (ADHD), children with autism, ageing population, adults concerned with cholesterol problems and communicable diseases, other adults with general health concerns and those with digestive concerns.

A CASP (Critical Appraisal Skills Programme) tool is used to evaluate and analyse the ten quantitative and qualitative studies selected. A CASP tool is designed to help reviewers make sense of evidences. This is achieved through a series of 11 questions that assesses the validity, results and applicability of studies to the aim of this meta-analysis.

A reconstructed HRQOL tool (Table 1) was also used in this meta-analysis which contains domains and indicators to define HRQOL's, validated by biophysiologic instruments (Gil & Feinstein 1994). To explain further, the tool quantitatively evaluated the probability values of the ten selected studies and qualitatively analysed its relationship to the six domains of the HRQOL. The biophysiologic instruments served as an additional tool to measure the validity of the analysed and evaluated results from the ten selected study trials.

Carr and Higginson (2001) and Cella and Tulsky (1990) agreed that study trials of HRQOLs are reliably measured if biophysiologic instruments are used to validate domains and indicators.

The tool was used to compare and contrast the ten selected studies in order to identify differences in indicators that correspond to the domain differences (Guyatt *et al.* 1993) (Table 1).

Table 1. The reconstructed tool of the HRQOL — Six domains and indicators validated by biophysiologic instruments.

Domains	Indicators defining each domain	Biophysiologic instruments
Domain I Physical	1. Pregnancy, pain threshold, vital signs, sleep, comfort and rest — normal feeling 2. Cellular energy, blood circulation and metabolism — blood investigation 3. Control genetic abnormality — congenital or developing on their adult stage	• Blood investigation: ↑ hemoglobin count, RBC, iron, progenitor cells and normal WBC; negative result on rhesus incompatibility test; no genetic abnormalities • Electroencephalography test: Developed prefrontal brain cortex and memory functions • Chest X-ray: Normal heart size and no lung problems • Colonic transit time: Normal bowel movement
Domain II Psychological perceptions	4. Positive outlook is felt 5. Thinking, learning, memory and concentration is effective 6. Self-esteem is high 7. Negative body image disturbance 8. No negative feelings	• Physical Exam: Decreased dryness and thirst problems • ↑ attention span, concentration and social interactions • Good result on intelligence quotient tests with good memory
Domain III Level of independence	9. Mobility — active life 10. Activities of daily living 11. Dependence on medication or treatments aside from food supplement 12. Capacity to work independently	• Physical Exam: Normal body mass index • Bone scanners: Increase bone and muscle mass • Timed up and go test: Increase in mobility
Domain IV Social relationships	13. Good mood or good affect 14. Motivated and motivating others 15. Sexual activity — fertile 16. Social inclusion — capacity to socialize	• Physical exam: ↑ sexual drive • Modified checklist on physical exam: Well motivated and good communication skills • Self-rated health scale: (+) social skills; (–) stress
Domain V Environment	17. Location of residency, work or refuge is safe and secured 18. Home environment is conducive 19. Financial resources are met from environment 20. Tolerated atmospheric pressure 21. The space is enough to acquire new skills and access to actively acquire resources 22. Good for recreation/ leisure activities 23. Free from environmental hazard — chemicals, micro-organisms and polutions 24. Adopts to all forms of transportation	• Physical exam: ↑ resistance to infection and ↓ incidence of falls • Self rated health scale: Conducive home environment and work area
Domain VI Spirituality/ religion/ personal beliefs	25. Evidence of acceptable spiritual perceptions 26. Forgiveness and Blame is balanced 27. Concerns about religious beliefs 28. Concerns to achieve a dignified death	• Blood extraction: ↑ in the production of progenitor and endothelial cells • Self rated health scale: Stress free mind

The domains and indicators used in this tool came from the European's QOL (EuroQOL Group 1996), the Office of Population, Censuses and Survey's (OPCS') QOL (Bowling 1995), the Nottingham health profile's (NHP's) QOL (Hunt *et al.* 1986) and the 36-item short-form health survey's (SF-36's) QOL (Ware & Sherbourne 1992).

Bowling (1997), however, said that caution must be taken while reconstructing domains and indicators of HRQOLs so that it will complement each other. Table 2 enumerates the domains and indicators of EuroQOL, OPCS, NHP and SF-36.

Ethical Issues

Primiarily, autonomy on selecting health products is an individual decision because it is bought over-the-counter without medical prescriptions. Lastly, the benefit of achieving significant domain/s of a HRQOL outweighs the inevitable harm of getting side effects from commercially prepared food supplements, multivitamins and minerals.

Table 2. The EuroQOL (EuroQOL Group 1996), OPCS (Bowling 1995), NHP (Hunt *et al*. 1986) and SF-36 (Ware & Sherbourne 1992)

General domains and indicators	EuroQOL	OPCS	NHP	SF-36	Reconstruction
Pain, vital signs, genetic abnormality and concentration	+	–	+	–	Indicator
Energy or tiredness, cellular energy, metabolism and blood circulation, comfort and sleep	+	–	–	+	Indicator
Negative feelings, socialization, body image and mobility	–	–	–	–	Indicator
Physical or physiologic	+	+	+	+	Domain
Level of independence and daily activities	+	+	+	+	Domain
Social relationships	+	–	+	+	Domain
Environment safety and leisure	+	+	–	+	Domain
Relationships, self esteem, positive outlook in life, mood, forgiveness, spiritual perception and material needs	–	–	–	+	Indicator
Sex, sexual urge and pregnancy	–	–	–	+	Indicator
Work, home, recreation, atmospheric pressure, environmental hazards and transportation	+	–	–	+	Indicator
Emotional well being and spirituality	+	+	+	+	Domain
Dependence or independence on treatments, dignified death and financial resources.	–	–	+	–	Indicator
Psychological perceptions	+	+	+	+	Domain
Perceptions of future	+	–	–	–	Indicator

RESULTS

Table 3 shows the qualitative results after comparing and contrasting the ten selected studies against the indicators and domains of the reconstructed HRQOL tool in this meta-analysis relevant to the extrinsic factors.

Pregnant women using multiple micronutrients did not manifest a significant HRQOL affected by age, location of residency and genetic/ethnicity. The aging population using supplements showed significant effects on the HRQOL having six domains, followed by the adult population using multivitamins with significant five domains while children are identified with the least number of significant domains affected by the extrinsic factors.

Table 4 enumerates the quantitative results of the ten selected studies' probabilities, the population sample sizes and the populations demonstrating self care that are used to evaluate and analyse a significant HRQOL. Of the ten studies, nine demonstrated self care (Orem 1991) leading to a significant HRQOL with an odds ratio (OR) of 90% and a probability value of <0.05.

The focused populations using multivitamins, minerals and food supplements do achieve significant domains of the HRQOL.

DISCUSSION

Self care starts from maternal conception and the beginning of fetal development until an individual reaches the aging process (WHO 2004).

Most pregnant women demonstrate self care by drinking Iron fortified milk and multiple micronutrients regardless of their age and ethnicity because it contributes majorly to the quality of fetal development (Hilton 2003).

The HRQOL among pregnant women using multiple micronutrients and Iron fortified milks shows blood investigation results with an increase in hemoglobin count of greater than 110 milligram per deciliter during their perinatal period from the first trimester to the third trimester (Shankar 2008). However, hemoglobin count can be affected by the environmental domain such as the location of residency (Hilton 2003) making the evaluation of a HRQOL invalid. Pregnant women who live in mountainous areas can experience Megaloblastic anemia (Tortora & Derickson 2010) a condition related to the atmospheric pressure in the environment that increases hemoglobin count confirmed by blood investigation (Black & Hawks 2008), affecting fetal live births (Hilton 2003; Roy *et al.* 1997).

Table 3. The qualitative results.

Populations	Domains	Extrinsic factors	Indicators
Pregnant women using multiple micronutrients	None	Age, location of residency and genetic/ethnicity	None
Children with ADHD using vitamin C, Iron, Zinc and Omega 3	Level of independence, physical, social and psychological	Ethnicity/genetics, age and health status	ADL, metabolism, mood and genes
Children with autism using stem cells	Physical, psychological and social	Health status and ethnicity/genetics	Self esteem, social inclusion and genes
Normal toddlers using DHA milk formula	Physical and psychological	Health status and genetics/ethnicity	Cellular energy, WBC, RBC and concentration
Adult men and women using virgin coconut oil, *moringa*, probiotic fermented milk, vitamin E, beta carotene, chlorophyll and beta glucan barley	Physical, psychological, level of independence, environmental and social	Health status, location of residency and genetics/ethnicity	Capacity to work, safe place to stay, socialization, metabolism and immune response
Ageing populations using stem cells, minerals high in calcium, vitamin D and multivitamins	Physical, level of independence, social, environmental, psychological and spiritual	Gender, location of residency and health status	Cell energy, mood, mobility, home environment, genes and spirituality

In the absence of environmental factors, Shankar (2008) validated an evidence of newborn infant death that is significant with the usage of multiple micronutrients ($p = 0.07$) affecting the physical domain of the HRQOL among pregnant women ($n = 15\ 804$). On the contrary, Shankar (2008) argued that these newborn infant deaths are also associated with women's age as they start to get pregnant at their menopausal stage thus coincidently requires them to use high amount of multiple micronutrients.

Another coincident requires pregnant women to take multiple micronutrients as a form of food supplement if the fetus is confirmed to have a positive blood rhesus incompatibility coming from maternal ethnicity resulting to a maternal and fetal genetic miscoding which does not assure live childbirths (Black & Hawks 2008; Tortora & Derickson 2010). However, it is also disagreeable that pregnant women with successful live childbirths are as such, because of an undeclared use of multiple micronutrients (Hilton 2003).

On the other hand, not all successful live childbirths will grow up with a qualitative life relative to their level of independence (refer to Table 1, No. 10). For example are children recognised to have a genetic disorder called ADHD. Children identified with ADHD came from a genetic lag during maternal conception (Black & Hawks 2008) (refer to Table 1, No. 3).

According to Black & Hawks (2008), ADHD as a child's developmental deviation can be confirmed using electroencephalography, which reveals changes in brain waves with associated decreased energy and susceptibility to fatigue. The prefrontal brain cortex developmental immaturities are affecting the children's HRQOL (Saris *et al.* 2011; Black & Hawks 2008; Tortora & Derickson 2010).

The HRQOL is significant among ADHDs ($n = 233$) who demonstrates self-care using commercially prepared vitamin C, Iron, Zinc and Omega 3 ($p = 0.008$). The ADHDs HRQOL is evaluated with a decrease in the children's skin dryness and decrease episodes of thirst problems (Saris *et al.* 2011) (refer to Table 1, No. 2). These improved physical domain lead mothers to lessen the frequency of the use of therapeutic drugs called Selective Serotonin Reuptake Inhibitors for ADHDs as validated by Sinn & Bryan (2007). In addition, ADHDs social domain associated for both male and female children with cognitive mood disturbances also improve (Sarris *et al.* 2011; Sinn & Bryan 2007) (refer to Table 1, No. 13).

Another genetic disturbance from fetal development is called autism that is found on every one out of one hundred and sixty-six children all over the world (Black & Hawks 2008; Ichim *et al.* 2007). Autistic children with genetic altered neuro-developmental conditions and neural hypoperfusion who are diagnosed using a modified checklist for autism in toddlers (Robins & Dumont-Mathieu 2006) demonstrates self care using anti ageing food supplements with stem cell enhancers (Boris *et al.* 2007) to improve their physical and psychological domain. Ichim *et al.* (2007) validated that the autistic children's ($n = 100$) social interaction, communication, awareness of self and an increase in the attention span is evident ($p = 0.001$) (refer to Table 1, No. 6 and 16). Their genetic

Table 4. The quantitative results.

Studies	Populations demonstrating self care	Probability (p =)	Sample size (n =)	Probability interpretation
Shankar 2008	Pregnant women using multiple micronutrients	0.70	15 804	HRQOL is not significant on fetal and maternal health
Minns *et al.* 2010	Toddlers using DHA milk formula	0.007	20	HRQOL is significant on the ADL, concentration and blood circulation
Sarris *et al.* 2011	ADHD using vitamin C, Iron, Zinc and Omega 3	0.008	233	HRQOL is significant on the children's brain cognition and physical activities
Steptoe *et al.* 2004	Self rated health on adult men and women age 18–70 years using beta carotene, vitamin C and E.	0.001	245	HRQOL is significant on their capacity to work and positive outlook in life
Mahajan & Mehta 2010	Moringa oleifera on all adults with decrease in immune response	<0.001	100	HRQOL is significant to increase their immune response, tissue regeneration
Shilling *et al.* 2013	Virgin Coconut oil on all adults with decrease in immune response	<0.001	34	and to their micro-organism infected environment
Keogh *et al.* 2003	Adults aged 18–65 years using chlorophyll and beta glucan barley	0.001	18	HRQOL is significant with manifested healthy liver and healthy thyroid based on blood and urine samples
Gage & Fernandes 2009	Healthy adult men and women using probiotic fermented milk.	0.001	396	HRQOL is significant on their daily defecation and decrease bloatedness after eating.
Grieger *et al.* 2009	Ageing women using minerals high in calcium, vitamin D & multivitamins	0.01	49	HRQOL is significant on their muscle strength and energy
Ichim *et al.* 2007	Autism Food supplements with stem cell enhancers	<0.001	100	HRQOL is significant in controlling ageing
	Ageing		500	

9 out of 10
OR= 90% and p = <0.05

abnormalities are regenerated and rejuvenated (Ichim *et al.* 2007) (refer to Table 1, No. 3).

On the other hand, normal toddlers ages 18–36 months (n = 20) demonstrates self care using milk and dairy products fortified with docosahexaenoic acid (DHA) to improve their HRQOL (p = 0.007). The physical domain of normal toddlers who use DHA fortified milk products showed an increase in plasma red blood cell count; a normal white blood cell after blood investigation and a normal chest x-ray result (Table 1, no. 2) while their psychological domain manifest good memory and concentration and focus confirmed by intelligence quotient (IQ) tests (Table 1, n o. 5) (Minns *et al.* 2010). The WHO (2003/2002) validated that the physical domain of the HRQOL among normal toddlers can be achieved using DHA food supplements regardless of their previously experienced physical illnesses such as cancer, heart diseases and respiratory illnesses. However, as children grow older, their recommended vitamins, minerals and food supplements to improve their HRQOL also change.

The HRQOL is highly significant among the adult men and women age 18–70 years (n = 245) who demonstrates self care using commercially prepared beta-carotene and vitamin C tablets and vitamin E capsules as an additional protection from stress (p = 0.001) (Steptoe *et al.* 2004). The adult's HRQOL improves and is measured by their

capacity to work, positive outlook and confidence (WHO, 2002; Limon-Pacheco & Gonsebatt 2009) (Table 1, no. 12 and 4). The outcomes of their HRQOL are measured using general self-rated health that evaluates their level of independence and psychological domains (Steptoe et al, 2004). However, positive outlook in life and capacity to work are affected by the adult's health status (Department of Health 2003). Adults who get sick often affect their HRQOL (Fahey 2005).

The HRQOL, in its physical domain is significant among adults with decrease in immune response, demonstrates self care (Orem 1991) through use of *Moringa oleifera* ($p = <0.001$) (Mahajan & Mehta 2010) and virgin coconut oil ($p = <0.001$) (Shilling *et al.* 2013).

Virgin coconut oil is found to have a significant increase in white blood cells and hemoglobin count and good hepato-protective activities against infection confirmed through blood investigations on adults ($n = 34$) with decrease in immune response (Shilling *et al.* 2013) (Table 1, no. 2). WHO (2003) and the Food and Drug Administration (FDA) (2012) validated that coconut extracts are also used on anti-ageing food supplements to regenerate dead and micro-organism infected cells and tissues.

While Farooq Anwar *et al.* (2007) and Jonathan *et al.* (2012) validated that Moringa seeds, commercially prepared as food supplements help in anti-oxidation of dead or infected cells, anti-inflammatory, antipyretic and increase cellular regeneration assessed thru physical examination. Adults with decreased immune response takes Moringa oleifera to enjoy their surrounding ($n = 100$) (Mahajan & Mehta 2010). Kasolo *et al.* (2010) says that these adults in rural communities with decrease in immune response worry less on their micro-organism invaded environments (Table 1, no. 23) and enhance their capacity to work (Table 1, no. 12).

However, having a hazard-free environment and the capacity to work can still affect the HRQOL with hormonal changes (Behall *et al.* 2004; McIntosh *et al.* 1991). Adult men and women have different hormonal changes that affect bowel peristalsis (Gage & Fernandes 2009), health maintenance, iron production (Shankar 2008) and fat absorption thus affecting their capacity to work (McIntosh *et al.* 1991). Hormonal changes also vary with ethnicity leading to obesity confirmed through physical examination and blood investigation (Black & Hawks 2008; Tortora & Derrickson 2010).

The HRQOL is significant ($p=0.001$) among adult men and women with obesity ($n=18$) caused by hormonal changes as they demonstrate self-care using fiber food supplements with chromium and beta glucans (Keogh *et al.* 2003). The obese adults' HRQOL is evident in a blood investigation result with decreasing cholesterol counts and maintaining a normal body mass index after taking fiber diets (Deng 2009) (Table 1, no. 2). Fiber diets combined with high amount of chromiums and beta glucans have been validated by Behall *et al.* (2004) and Sadri *et al.* (2012) to improve the level of independence and the physical domain of adult men and women with obesity. The presence of chlorophyll from chromium rich food supplements also helps in the detoxification and increases their immune response (Sadri *et al.* 2012) in addition to their decreasing cholesterole (Deng 2009; Behall *et al.* 2004) (Table 1, no. 2).

However, normal adults must still demonstrate self-care by diet and food control (Gage & Fernandes 2009). Normal adults are influenced to change diets and foods based on the location where they stay (Smith-Warner *et al.* 2000). Smith-Warner *et al.* (2000) added examples of frequently changing diets, such as regular or occasional alcohol consumption and eating raw and uncooked foods. These changing diets lead to bloatedness after overeating, irregular daily bowel movement as confirmed by colonic transit time (Gage & Fernandes 2009) and infertility confirmed by blood laboratory results (Bertazzoni *et al.* 1993; Smith-Warner *et al.* 2000). In order to improve their bowel movement, these healthy adult men and women ($n = 396$) demonstrates self-care (Orem 1991) by using commercially prepared probiotic fermented milk-containing Bifidobacterium Lactis (Gage & Fernandes 2009), regardless of the manner of consuming or route of the administration, to improve their HRQOL's physical domain ($p=0.001$).

Fiber diets with chlorophylls and probiotic fermented milk-containing *Bifidobacterium Lactis* regulates uncontrolled eating habits and normalises daily bowel movements of not more than twice a day (Table 1, no. 2) as validated by WHO (2010) and Bertazzoni *et al.* (1993). These activities are also known as a hypothalamic regulation that also affects their reproductive hormones, increasing their sexual drive (Bertazzoni *et al.* 1993; Tortora & Derickson 2010) (Table 1, no. 12).

A balanced metabolism, a good systemic immune response and a healthy reproductive system can result to a good ageing process associated with hormonal changes (Bertazzoni *et al.* 1993; Smith-Warner *et al.* 2000; Black & Hawks 2008). However, it is inevitable for the ageing population to have degenerated cells (Tortora & Derickson 2010).

The ageing adults ($n = 500$) who demonstrate self care use food supplements with precursor cells or stem cells enhancers to develop, repair, restore and regenerate their blood, lymph, brain, bones and other organs (Ichim *et al.* 2009) (Table 1, no. 3).

This is validated by Ichim *et al.* (2007), which stated that food supplements with stem cells is significant in

achieving HRQOL (p = <0.001) since it can regenerate mesenchymal stem cells found in bone marrow, blood, dermis and periosteum and make old tissues young again confirmed thru blood investigation. However, the HRQOL for all ageing populations differ with regards to gender. Ageing women's HRQOL also require strong bones in addition to having smooth skin (Agero & Verallo-Rowell 2004) and regular tissue regeneration (Grieger *et al.* 2009; Mikirova *et al.* 2009). Menopausal ageing women are prone to have weak bones seen on bone scans (Tortora & Derickson 2010).

A factor affecting the HRQOL among menopausal women is their location of residency leading to falls and health status that weakens their bone mass and muscle strength (Grieger *et al.* 2009; Mikirova *et al.* 2009; Black & Hawks 2008). The HRQOL is significant (p = 0.01) among ageing women (n = 49) who demonstrates self care by using calcium carbonate and vitamin D, regardless of the manner of consuming or the route of administration, to decrease their incidence of falls (Grieger *et al.* 2009) from their area of residency (Table 1, no. 9 and 18). Grieger *et al.* (2009) studied that these ageing menopausal women who use multivitamins with high amount of calcium carbonate and vitamin D also increases their muscle strength and energy (Table 1, no. 2).

Broe *et al.* (2007) and WHO (2002) validated an increased energy for the ageing women taking calcium carbonate and vitamin D confirmed thru the handgrip strength timed up and go test that evaluates their bone and muscle strength (Grieger *et al.* 2009). However, aging men also need muscle strengths to make their life more active.

Both ageing men and women (n = 500) using food supplements with stem cells and progenitor cells can significantly increase their bone and muscle strength (Ichim *et al.* 2007; Mikirova *et al.* 2009; FDA 2012) (p = <0.001).

Mikirova *et al.* (2009) studied that stem cells on food supplements are anti ageing for a more active lifestyle. In addition, stem cell enhancers can also improve aging men's penile erection problems called impotence since penis involves muscle strength and contraction (Mikirova *et al.* 2009; FDA 2012).

Zhao *et al.* (2009) validated that signs of stem cell activities are present with blood laboratory evidence that confirms a change in the ageing hematopoietic and endothelial progenitors thus delays the ageing process for more active years – socially and physically (Table 1, no. 2 and 9).

Regarding the HRQOL in the domain of spirituality, it is phenomenological that anti ageing food supplements improve spiritual perceptions (Mackey 2003; Mikirova *et al.* 2009) (Table 1, no. 25). People consuming this food supplement becomes more forgiving and spiritually inspired as validated by Spindler *et al.* (2008) using ethnographic case studies presenting the religious anti-ageing narratives of German-speaking anti-ageing movement. Anti-ageing food supplements regulate the emotions and control mood depressions thus making the ageing populations balance their perceptions on forgiveness and blame (Spindler *et al.* 2008; Mikirova *et al.* 2009; Mackey 2003) (Table 1, no. 13, 26 and 27).

RECOMMENDATION

According to FDA (2012), healthcare professionals must recommend commercially prepared multivitamins, minerals and food supplements when bought over-the-counter, with the seal of approval from government-owned drug auditing companies.

Ethically, healthcare professionals should emphasise during health promotions that displays of health claims are unlikely to be allowed on the health products' labels (National Health and Medical Research Council 2006; FDA 2012; Scientific Committee on Food 2001).

Recommending natural health products is still the best option. Obiajunwa *et al.* (2002) said that plant names and plant parts as food supplements with vitamins and minerals (Table 5) are one of the classic ways of health promotion, and are more proven to achieve almost all of the six domains of the HRQOL.

But nowadays, plant parts are commercially prepared.

The contemporary way of recommending commercially prepared health products requires more caution that is based on specific needs of organ systems related to the five extrinsic factors (Black & Hawkes 2008; Tortora & Derrickson 2010).

The young adolescent populations need to consider their age, gender and health status when consuming multivitamins, minerals and food supplements since changes on their physical and mental health are still developing. Health promotions are important to select the most significant over-the-counter multivitamins, minerals and food supplements that have the ability to achieve the physiologic, psychologic and social domains of a HRQOL (Mikirova *et al.* 2009; Keogh *et al.* 2003; Smith-Warner *et al.* 2000).

As these young adolescents become adults, gender hormones and ethnicity affect their manner of selecting multivitamins, minerals and food supplements, thus making it more complex for healthcare professionals to promote self care (Orem 1991), to achieve a significant HRQOL.

Table 5. Plant names and plant parts used in the classic way of doing health promotions (Obiajunwa *et al*. 2002)

Plant name	Common name	Purpose / Use	Plant part
Acalypha wilkensiana	Copper leaf	Fungal skin	Leaf
Alchornea cordifolia	Christmas bush	Anti diarrhea	Leaf
Azadirachta indica	Nim tree	Liver function	Leaf
Calotropis procera	Sodom apple	Steroid	Leaf
Cassia alata	Tropical shrub	Anti eczema	Leaf
Chromoluena odorata	Sunflower plant	Allergic reaction	Leaf
Citrus aurantifolia	Lime tree	Skin dryness	Leaf
Datura metel	Devil's trumpet	Hair shampoo	Leaf and fruit
Eugenia uniflora	Brazilian cherry tree	Antioxidant	Leaf
Euphorbia hira	Pantropical weed	Anti protozoa / dengue	Aerial parts
Cyclosorus afer	Tropical fern	Reproductive health	Leaf
Ficus exasperate	Fig tree	Anti arthritic	Leaf
Laportea aestaan	Nettle tree	Bone diseases	Aerial parts
Mangiferia indica	Mango tree	Antiemetic	Leaf
Mamordica charantia	Bitter melon plant	Stomach ache	Aerial parts
Ocimum gratissimum	Wild basil	Anti tumor / cancer	Leaf
Phyllanthus niruri	Berry under	Jaundice	Leaf
Spondias monbin	Yellow plum plant	Birth control	Leaf
Zingiber officinale	Ginger plant	Cardiovascular diseases	Rhizome

As adults age specific needs also change because they need to consider their degenerating organ systems. Healthcare professionals must choose food supplements, multivitamins and minerals that has the ability to maintain homeostasis on the aging's organ system in order to achieve all six domains of HRQOL especially if they are dying.

Lastly, children with genetic abnormalities and physical disabilities must consider adult assistance to help them purchase or buy commercially prepared multivitamins, minerals and food supplements because they cannot generate their own funds.

Generally, adults buying health products for children should seek for medical advices, especially if extrinsic factors can affect a specific domain of their HRQOL.

Consultations from specialists are highly recommended to be primarily sought, since it is difficult to assess specific needs, to achieve the six domains of the HRQOL using commercially prepared food supplements, multivitamins and minerals.

CONCLUSION

In order to balance the six domains of the HRQOL, self care must be based on the specific needs of individuals. That is why promoting commercially prepared health products must be based on an individual's specific needs.

The HRQOL is therefore evaluated and analysed as a theoretical outcome of self care.

It is therefore concluded that there is a significant relationship between age, location of residency, gender, health status and ethnicity/genetic that affects the six domains of the HRQOL.

It is also concluded that commercially prepared food supplements, vitamins and minerals significantly demonstrated self care to achieve an individual's HRQOL (OR = 90% / p = <0.05).

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Is Malaysia Headed for El Nino?

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In late 2013, when preparing the *ASM Annual Report* for 2013, I had reported under the section on "Looking Ahead" for 2014 that Malaysia was headed for an El Nino year. I had stated that "Scientists are now predicting that 2014 will be an "El Nino" year, a year when temperatures will rise. An El Nino year is when Southeast Asia, and other parts of the region, is associated with unusually dry conditions. So, will Malaysia now be affected by droughts?"

Although February is often the driest month, what we are witnessing today had also affected areas, including, incredibly, Malaysia's "wettest town", Taiping. The Malaysian Meteorological Department (MMD) had forecast that Malaysia will be facing more dry months during a five-month period beginning from the middle of May due to the dry-blowing southwest monsoon season after a brief respite of "frequent afternoon thunderstorms" in the inter-monsoon months till then.

The World Meteorological Organization (WMO) had reported in mid-April 2014 that, although "the latest outlooks from climate models and expert opinion suggest that oceanic conditions and atmospheric anomalies associated with El Niño or La Niña are most likely to remain neutral into the earlier part of the second quarter of 2014". However, WMO further reported that they had observed that "since February there have been two strong westerly wind events and a general weakening of trade winds in the tropical Pacific". This phenomenon had led to "a significant warming of the waters below the surface of the central Pacific, which historically has been a precursor to El Niño development". WMO cautioned that this may not lead to an El Niño event. Nonetheless, the Organization pointed out that "the longer the trade winds remain weakened, and subsurface temperatures stay significantly warmer than average, the higher the likelihood of the emergence of an El Niño".

WMO further stated that their model forecasts indicate a fairly large potential for an El Niño, "most likely by the end of the second quarter of 2014". The models surveyed predict that approximately two-thirds of the thresholds will be reached for an El Niño for the June to August period while the remaining models predict a continuation of neutral conditions. A few models predict an earlier El Niño onset, such as in May. No model suggests a La Niña in 2014. WMO also said that the strength of the possible El Niño could not be reliably estimated at the current time. This uncertainty is related to the fact that model outlooks that start in March-April tend to have lower skill than those made later in the calendar year, due to the more fluid nature of the ocean-atmosphere system during March to June. WMO ominously mentioned that if El Niño does develop by the end of the second quarter of 2014, it is likely to continue through the remainder of the year.

A hot and dry weather from mid-year onwards for Malaysia means that we will be faced with another water crisis, or that the current water crisis continues until the third quarter of the year when the moisture-laden north-east monsoon begins. Until then, our agricultural output, specifically palm oil and rice, will be affected negatively in terms of yield. With poor yields, in the case of palm oil, this will inevitably give rise to high commodity prices as stockpiles begin to fall. In the case of rice, Malaysia may need to import more from overseas and also assist financially our *padi* farmers. Of course, the global price of rice may also increase. El Nino for sure will impact our agricultural produce in general and food security specifically. Agriculturally, not only will onshore areas be affected, worse still, marine life will also be affected by El Nino through the reduction in the upwelling of nutrient-rich water that is necessary to support the large fish population of Malaysia's waters. Our marine parks may also be affected due to acidification and warm water temperatures cause coral bleaching.

Climate change effects may add to the El Nino phenomenon by making matters worse, especially with the reported increase in temperature from the burgeoning green-house-gases emissions released by human activities.

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Malaysia's Initiatives

It is clear that Malaysia needs to be well-prepared to face up to the challenges with regards to El Nino and its attendant impacts. In so far as GHG emissions are concerned, Malaysia, even though it is a small country is nevertheless committed to adopting an indicator of a voluntary reduction of up to 40 percent in terms of emissions intensity of gross domestic product (GDP) by the year 2020 compared to 2005 levels as mentioned by the Prime Minister during COP 15 in 2009 in Copenhagen. The indicator is however conditional upon the transfer of technology and adequate financing from Annex 1 partners (industrialized countries and economies in transition). The Prime Minister further reiterated that Malaysia remains committed to ensuring at least 50% of its land area remains as forests as pledged in the Rio Summit. Currently, the nation's natural forests and agriculture crop plantations combined cover 75% of the country's land area. From the data released after the Second National Communication by the Ministry of Natural Resources and Environment, this target of 40% emissions intensity of GDP seems achievable.

The Third Outline Perspective Plan (OPP3), launched in 2001, on Sectoral Strategies and Practices regarding the environment highlighted the need for a National Water Policy which was to be formulated in the 8th Malaysia Plan (2001–2005) to provide a framework for water conservation and management to ensure adequate and safe water supply for the nation. "The focus of the policy will be on the integrated river-basin approach; the protection of catchment areas and reservoirs; and addressing the issues of inter-State and inter-basin water transfers". In line with this decision, a National Water Resources Study (2000–2050) was completed in 2000. A review of the National Water Resources Study (2000–2050) was subsequently undertaken in 2010 and the National Water Resources Policy launched in March 2012. What is still in the process of acceptance by all parties is the draft National Water Resources (NWR) Act, to replace the *Waters Act* of 1920. As part of the Explanatory Notes in the draft NWR Act, it states that the proposed Act "seeks to provide, through the adoption of the principles of integrated water resources management, for the implementation of a national policy for a more uniform and consistent approach to the sustainable development, use and conservation of water resources in Malaysia".

"The *Waters Act 1920 [Act 418]* is the current law which provides for the adoption of a more uniform and consistent approach to the control and regulation of water resources in the country. After more than 90 years, the *Waters Act* is out dated and no longer appropriate for current requirements. It also does not provide an appropriate role for the Federal Government in the sustainable development, use and conservation of water resources".

"The proposed Act will enable national and state authorities to manage all water resources including rivers, water bodies, ground water and storm-water in accordance with globally accepted principles of integrated water resources management".

Once adopted, the Act will ensure that Malaysia lives up to the Principles as enshrined in the Dublin Statement 1992.

Also, Malaysia is already committed to implementing **Integrated Water Resources Management (IWRM)** for the sustainable management of the country's water resources since the late 1990s. The National Water Resources Policy further reaffirms the adoption IWRM which calls for the balanced development and management of "water as a resource" and "water for livelihood". Implementation of the IWRM agenda involves the integration both natural and human systems set within an overall framework that provides the enabling environment with effective institutional arrangements and supported by necessary management instruments. It is therefore clear that the implementation of IWRM principles across all sub-sectors and levels of hierarchy are guided by the internationally endorsed *1992 International Conference on Water and the Environment (ICWE) Dublin Principles*.

IWRM, a sub-set of Integrated Natural Resources Management (INRM) (and comprising land, water, forests, minerals, wildlife and fisheries), is:

The Dublin Principles on Water (ICWE 1992)

Principle No. 1—Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment
Principle No. 2—Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels
Principle No. 3—Women play a central part in the provision, management and safeguarding of water
Principle No. 4—Water has an economic value in all its competing uses and should be recognized as an economic good

A process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".

Water Resource Management

So, where does Malaysia stand in so far as its water resources management is concerned? A water resources management report card would show a fairly dismal outlook. Our nation's water quality of water sources (rivers, lakes and reservoirs, and shallow groundwater) have deteriorated. There has increased flooding and flash floods. There is also temporal and spatial variability with a number of 'water-stressed' growth regions, or "deficit states" which the NWRS Review identified as being Perlis, Kedah, Pulau Pinang, Selangor and Melaka. There seems to be fragmented management and conflicts among sectors, viz. between consumptive use (potable water, agricultural water and ecosystem services) and non-consumptive use (hydropower, navigation, recreation and eco-tourism). All these issues are worsened with the emerging impacts of climate change. There is therefore a pressing need for improved and integrated management and water should be made everybody's business.

Role of the Academy of Sciences Malaysia in IWRM

In playing its role as the eminent science and technology "think-tank" in the country, the Academy of Sciences Malaysia (ASM) had, since 2008, been undertaking studies pertaining to the water sector, considered strategic for the country's economic development. The studies have been overseen by a dedicated ASM Water Committee. Adopting IWRM as the central thrust and noting that IWRM *per se* is a rather abstract concept, the Committee had, for practical application in the Malaysian context, broken down IWRM into discrete sub-sets or sub-themes.

One of the sub-themes was on lakes and reservoirs. In 2010, the Water Committee produced an advisory report, entitled *Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia*. This advisory report was produced as a result of an earlier study in 2005 on the status of 90 lakes and reservoirs in the country. These water bodies, covering some 100 000 ha and holding over 30 billion cubic metres of water support numerous economic, recreational and social functions. The study determined that about 62% of the 90 lakes are eutrophic, or nutrient-rich, while the balance was mesotrophic. This deterioration of the water quality is a serious concern. The advisory report recommended eight strategies and was submitted to the National Water Resources Council which adopted the recommendations for implementation by the Government. It is timely that an assessment of the lakes'/reservoirs' water quality be undertaken in order to determine if the water quality of the lakes, our water bank, have improved or worsened.

In 2011, in another study by the Water Committee on ground water resources in the country, it was found that, currently only some 3% of ground water is being utilised, with the bulk being in Kota Bharu and its environs. The study determined that there was some 5 trillion cubic metres of ground water as gross storage with 64 billion cubic metres as recharge from rain water. The advisory report, entitled *Strategies for the Sustainable Development and Management of Ground Water in Malaysia through Integrated Aquifer Systems Management*, and recommending eight strategies, was submitted to the Ministry of Natural Resources and Environment for its consideration for implementation by the Government. The National Water Resources Study undertaken in 2010 determined that, of the 973 billion cubic metres (BCM) of rainfall that Malaysia receives yearly, some 63 BCM is groundwater recharge. Based on a Japan International Cooperation Agency (JICA) Study in 1982 conducted for the Government of Malaysia, it was estimated that groundwater storage amounted to a massive 5 trillion BCM. Demand of water by 2050 is however projected to be only 18.2 BCM. There is therefore sufficient groundwater to supply the needs of the nation without undue deleterious effects impacting inland or coastal areas. However, a detailed assessment of aquifer systems would first need to be undertaken by the Federal Government covering all 189 major river basins in the country. This assessment would include long-term pumping tests, conducted preferably during the dry seasons, from which "safe yields" would be calculated. The Minerals and Geoscience Department and those states which already have Water State Enactments would ensure that the "safe yields" are strictly adhered to and enforced.

Both these studies incorporated the use of science and technologies in addressing issues concerning lakes/reservoirs management and ground water (aquifer) management.

Water Sector Transformation

In making water everybody's business and in preparing for a future where water crises are issues of the past, Malaysia must initiate a water sector transformation, preferably to be achieved as by 2020.

Establishment of Rare Earth-based Industries in Malaysia (A Strategic New Source for Economic Growth)†

In September 2012, the Academy of Sciences Malaysia (ASM) established the ASM Task Forces on Rare Earths (TFRE) which saw the many opportunities in REs, from the upstream exploration and mining of RE-based minerals in the country, to cracking and processing in the mid-stream sector and finally to the down-stream sector, comprising value-added industries using RE metals in green technology applications. The whole ecosystem of REs would eventually contribute to the enhancing the nation's economic growth as well as providing many high-income jobs to Malaysians. The Task Force thus decided to publish a blueprint on REs.

The main aim of the Blueprint is to outline the necessary development approach and the roles to be undertaken by the various stakeholders for achieving the desired outcome of the proposed RE-based industry.

The Blueprint's objective is to provide the necessary information for the policy makers or investors to make informed decisions on establishing industries, whether in mining, in processing or in the many downstream industries using REs metals.

The principal goal is to initially use the local available resources containing heavy REs elements (HREEs) towards establishing a full REs supply chain, leading to the sustainable development of the high-tech industry in Malaysia.

In 2013, in a study published by the ASM (*Revitalising the REs Mineral Programme in Peninsular Malaysia as a Strategic Industry*) showed that, apart from alluvial xenotime and monazite (REs-containing minerals that are recovered as by-products of tin mining), there are other potential sources of REs which are worthwhile investigating, especially those associated with ion adsorption clays. Ion adsorption clays contain heavy RE elements (HREEs) and are basically thorium- and uranium-free, as opposed to xenotime and monazite, both of which contain thorium and uranium. Perak had been proposed as the first state for this investigation.

If, on investigation by the Government, the ion adsorption clays are found to occur in encouraging quantities, the state government should invite investors, whether as wholly local ventures or in joint-partnership with foreign expert mining companies to determine the economic viability of the resource. If the company finds that the deposit can be mined economically, the state government should award a mining lease to the company to mine the ore and process the ore to produce concentrates.

If the concentrate through-put is large, the company should preferably also have processing facilities on-site to process the concentrates to produce high-purity REs oxides (REOs) as the production of REOs will be a value-added initiative. Depending on the final use of the REOs, the relevant RE-based manufacturing companies can be invited to set up their plants in Malaysia.

If it is found that Malaysia does have "economical and minable reserves of HREEs", the expected desired outcomes are:

- to become a regional manufacturing center for RE-based and RE-enabled industries
- to become a regional center for the R&D on RE-based technology and products;
- to become a strategic location in the region for FDI to relocate their high-tech R&D and manufacturing activities; and
- to contribute to achieving the status of high-income nation through the strong economic multiplying effects created by the RE-related industries.

†A Report by the Academy of Sciences Malaysia Task Forces on Rare Earths.

The Blueprint provides details of road-maps in each sector of the full REs supply chain, that is, in the upstream, midstream and downstream sectors. The Government has a major role to play in the upstream sector of exploration, R&D and capacity building. The relevant Ministries have been identified. For the detailed investigations in upstream, mid-stream and downstream sectors, the role of the Government is to facilitate the entry of investors, whether local, foreign or as joint ventures of the two parties, into these sectors.

As a start, the Government would need to invest some RM10 million to explore for REs in ion adsorption clays in Perak. The allocation, to be given to Ministry of Natural Resources and Environment (NRE)/Minerals and Geoscience Department (MGD), will be used for undertaking reconnaissance field investigations. Once Perak is completed and the report submitted to the Government, the Government could provide additional allocation, amounting to RM30 million, for JMG to undertake similar studies elsewhere in the country.

As in any industry, there are always issues and risks to be managed. In this industry, the issues and risks cover the following areas:

- Impact on society and environment
- Global supply and demand
- Technology
- Forecasted reserves
- Available Expertise; and
- Research and Development

The full REs supply chain is a multi-billion ringgit when all three sectors are taken into consideration. Therefore, for the private sector to invest in Malaysia in this industry, various incentives and safeguards would need to be offered to attract them. Malaysia has the necessary institutions to ensure that these safeguards are vouched for. At the same time, the local universities and vocational institutes would need to produce the capable work-force needed to work in these high-tech industries.

In an initial assessment by the ASM, the expected minimal contributions of the REs industry to the national economy in terms of FDI, GDP and estimated employment are 2.4% (RM1.5 billion), 1% (RM 10.137 billion) and 0.04% (5000 jobs per annum) respectively, by year 2020.

To drive the full REs supply chain, there would need to be a driver of the national REs agenda, it is proposed that an Institute of Critical Materials Technology Malaysia (ICMTM) be established to play the roles pertaining to advanced and critical materials and the relevant industry sectors. ICMTM should be structured and organized such that it is industry-driven and with at least half of its board consisting of members from the industry.

INTRODUCTION

In September 2012, ASM initiated the ASM Task Forces on REs.

The Task Force continued the earlier initiatives of the joint ASM-National Professors' Council (NPC) which was tasked to produce a report on REs, entitled *Rare Earth Industries: Moving Malaysia's Green Economy Forward* as well as conduct a number of Forums to counter misinformation about REs through science and technology as a result of the Government's approval for Lynas' Corporation's to establish its Lynas Advanced Materials Plant (LAMP) in Gebeng Industrial Estate, Pahang. The Report was published in Bahasa Malaysia, Mandarin and English and distributed to various NGOs and members of the public at the events organised by ASM-NPC.

In its deliberations, the Task Force decided that REs was just not limited to the cracking and processing of REs concentrates as being currently undertaken by LAMP but that it should encompass a wider agenda. The Task Force saw the myriad opportunities in REs, from the upstream exploration and mining of REs-based minerals in the country, to cracking, processing and metals/alloys preparation in the mid-stream sector and finally to the down-stream sector, comprising value-added industries using REs metals in green technology applications. The whole ecosystem of REs would eventually contribute to enhancing the nation's economic growth as well as providing many high-income jobs to Malaysians — in effect, a new source of economic growth. The Task Force thus decided to publish a blueprint on REs.

A "Blueprint" is a numerically and graphically detailed set of directions created by engineers to enable other engineers to build or reproduce something. It is intended as a specific guide to be used by anyone. The Blueprint being presented here has a wider scope. It is intended to give all of the information necessary to the readers, be they policy makers or investors, who want to make an informed decision about implementing, or investing, in the creation of a total domestic RE supply chain in Malaysia. Such a supply chain would make Malaysia a competitive participant in the large and growing global market for mass-produced consumer products based upon REs-enabled technologies.

It must be made clear that:

- No technological impediment is foreseen to implementing the Blueprint, but, as with all large undertakings, there will be financial risks. Quantifying those risks is itself a principal function of this Blueprint.
- The opportunity being discussed here is for Malaysia to become a center for the manufacturing of RE permanent magnets, phosphors, lasers, and oil-refining catalysts. In order for that to come about Malaysia must first produce domestically or acquire control over the minerals from which critical REs can be extracted. In effect, Malaysia should begin exploring for its own REs-bearing minerals, especially those containing heavy REs elements. The potential of locally-occurring REs deposits was highlighted in a report of the Task Force, published in 2013 entitled *Revitalising the Rare Earths Mineral Programme in Peninsular Malaysia as a Strategic Industry*. The full implementation of the Blueprint shall be subject to Malaysia having "economical reserves of the heavy REselements (or, HREEs)".
- It will then be necessary for Malaysian industry to learn how to extract the desired RE elements from these minerals, separate the individual REs from each other and purify them to a level for industrial use. At this point, the separated and purified REs, a valuable group of commodities with a global market will be in production and be able to be sold globally "as is."
- The next step in the creation of a domestic Malaysian RE supply chain will be the creation of a domestic industry that produces, from the separated and purified individual RE elements, the individual high purity RE metals, alloys (for magnets and steel making), phosphors, and fine chemicals for the production of lasers, medical equipment, industrial equipment, and fluid cracking catalysts (for the oil refining industry). These "raw materials" produced at this stage will be also be saleable into the global high tech market "as is."
- Finally, a domestic Malaysian high-tech consumer and industrial end-use product industry will be created to manufacture and supply RE permanent magnets to the OEM automotive industry, the aerospace industry, the power generation industry, and the consumer portable electronic industries. Many of these industries already exist in Malaysia, such as OEM automotive and computer hard-disk drive manufacturing. These industries would be large-end users of REs permanent magnet-based components, such as electric motors and generators. The existing domestic Malaysian end-users of REs-enabled products will give the domestic REs component manufacturers a solid market anchor.

Outline of the Blueprint

The chapters in this Blueprint detail the necessary steps to achieve the above goals. The result will be a dynamic domestic manufacturing industry anchored upon a domestic total RE supply chain.

The Blueprint chapters include details on the global supply and demand of REEs, covering both the light and heavy REEs, the upstream sector (covering the potential occurrence of locally occurring REs minerals and the need to undertake exploration to determine their economic viability), the mid-stream sector (concerning the cracking, processing and production of metals/alloys from REs concentrates) and the downstream sector (which identifies industrial areas using REs metals which malaysia could establish) as well as identifying opportunities for a domestic total REs' supply chain in Malaysia and providing a road-map for all three sectors (including research aspects).

The other chapters in the Blueprint cover:

(i). Managing safety, awareness and environmental issues;
(ii). Identifying the necessary human capacity needs and the training facilities available locally and internationally from the vocational level to tertiary level;
(iii). The governance aspects (covering laws and regulations in all three sectors); and
(iv). The potential economic returns to the nation in terms of FDI, GDP and job opportunities;
(v). An appendix listing MIDA's incentives

THE RATIONALE FOR ESTABLISHING A RARE EARTHS-BASED INDUSTRY

It has always been known that, in Peninsular Malaysia, there are occurrences of REs-bearing minerals which have been mined as by-products of tin mining. Various sources, such as the United States Geological Survey reports for 2012 and 2013, have estimated that Malaysia had some 30 000 tonnes to 43 000 tonnes respectively of REs mineral reserves. The reserve figures for Malaysia mentioned above should however be taken with caution as the basis for arriving at those figures was never provided. As far as is known there has never been any country-wide REs resource evaluation exercise carried out in Malaysia.

The 2013 study by the ASM (*Revitalising the Rare Earths Mineral Programme in Peninsular Malaysia as a Strategic Industry*) showed that, apart from alluvial xenotime and monazite (these are REs-containing minerals that are being recovered as by-products of tin mining) and there are other potential sources of REs which are worthwhile investigating, especially those associated with ion adsorption clays. For example, after it was reported that, in southern China, the local populace was working on "ionic clays" around their farms and extracting HREEs, using simple chemicals to extract the HREEs, the Geological Survey of Japan experts examined similar deposits occurring in Vietnam and Laos and found to also contain HREEs.

In Peninsular Malaysia, there are areas in Perak and Selangor where similar deposits of ion adsorption clays are also found. In fact, in 2013, in a presentation by a Japanese Geological Survey expert to the ASM, he had reported that the samples he had collected from an area east of Kuala Lumpur contained encouraging amounts of heavy REs elements. The advantage of exploring for such ionic clay deposits is that the REs in these deposits are not associated with radioactive thorium or uranium. There is therefore an increased interest in identifying ion adsorption clays in similar geological environments in the Southeast Asian region and elsewhere.

HREEs are the strategic metals for producing green and high-tech products from wind turbines to smart-phones to military applications. These are critical metals for the production of high-end products by many high-tech companies in the world, such as Apple, GE, Boeing in USA, Toyota and Samsung in the East and including the global military-industrial complexes.

Having indigenous HREEs will give Malaysia a competitive advantage for establishing the high-tech industries, such as attracting FDI in high-tech industries. Mining, processing and separation of HREEs can be a new source of economic growth for Malaysia.

For Malaysia to develop a high-tech centered, domestically self-sufficient, REs-based consumer product manufacturing economy it will be necessary for it to secure first, for its own use, sources of the RE elements within Malaysia for competitive advantage and the technologies necessary to develop a domestic total RE supply chain, so that the REs-containing minerals mined within or imported to Malaysia can eventually be converted into components of consumer goods.

Such a RE total supply chain could be profitable immediately as it feeds the RE enabled technologies, such as computer storage (hard disk drives) and the manufacturing of the many RE permanent motors, generators, and sensors used on an automobile, and used in alternate energy production, and in domestic motor driven appliances, just to name a few, all of which are already being assembled in Malaysia with imported RE enabled components.

Malaysia has enough existing domestic demand for RE permanent magnets from its automotive and electronic manufacturing industries to support a total RE industry supply chain, and the south Asian regional demand coupled with the rapidly rising Chinese cost structure gives Malaysia a unique opportunity to become a competitive regional supplier of RE enabled finished goods.

As a Malaysian domestic total supply chain develops, it will be able to supply the critical core technology RE metals required to make RE permanent magnets, displays, lasers, and batteries to support not only the existing but also a larger domestic high tech industry that can manufacture consumer high tech items. Such items can be immediately exported, as they are now, and more importantly domestic production can be utilized to decrease outbound cash flows now required to support, by purchasing, finished retail goods, to feed the growing Malaysian domestic consumer demand for high-tech personal electronics.

AIMS, MISSIONS OR OBJECTIVES AND GOALS

The main aim of the Blueprint is to outline the necessary development approach and the roles to be undertaken by the various stakeholders for achieving the desired outcome of the proposed REs-based industry.

The main objective of the Blueprint is to provide the necessary information for the policy makers or investors to make an informed decision on establishing industries, whether in mining, in processing or in the many downstream industries using REs metals.

The principal goal is to use the local available HREEs resources for establishing a full REs supply chain, leading to the sustainable development of the high-tech industry in Malaysia.

The total REs supply chain consists of the following industries:

1. RE minerals (ores) mining (including the recovery of RE minerals, such as monazite and xenotime, as by-products of cassiterite (tin) mining or from locally occurring ion adsorption clays;
2. The extraction of the desired (in this case, the mixed RE) values from the ore concentrates produced in step one;
3. The safe removal of nuisance elements (mostly iron but also radioactive elements such as thorium and uranium found in monazite and xenotime) from the material produced in Step 2;
4. The separation and purification of the REs in commercial quantities from each other by solvent extraction, ion exchange, and possibly by newer cheaper and more efficient technologies such as solid phase extraction;
5. The preparation of high-purity RE metals, alloys, and forms from the products produced in Step 4 above;
6. The production of RE permanent magnets, batteries, lasers, and engineered chemicals leading to; and
7. The production of consumer products requiring RE permanent magnets, batteries, lasers, and commercial catalysts for automotive exhaust control and petroleum reforming.

Most of Steps 1 and 7 and Steps 2, 3, 4 already exist or have been done commercially in Malaysia. Steps 5 and 6 can be achieved with domestic resources alone (preferable approach) or by importing technology from politically reliable sources.

PROVEN DEVELOPMENT APPROACH

There are a number of strategies to adopt in approaching the development of the national REs resources, specifically of HREEs. These strategies are:

Exploration (Prospecting and Mapping) for HREEs reserves

As mentioned earlier, the Government should first initiate an exploration programme in Perak initially for REs-hosted ion adsorption clays (Figure 1). After this initial exploration programme in Perak is completed, it is proposed that a nation-wide exploration programme be initiated, possibly with technical assistance from either Japan or China through a G-to-G approach to map out areas with HREEs as well as light REs elements (LREEs).

In Perak, upon ascertaining the availability of reasonable amounts of HREE-bearing mineral deposits with HREE content viable for economical mining and processing, the Government (again through NRE/MGD) would need to proceed to:

a) To undertake research to find the alternative ways of mining, extraction and processing of ion adsorption clays which will have minimum societal and environmental impacts;
b) To formulate, if necessary, rules and regulations and guidelines for mining, extraction and processing of REs (the formulation of rules and regulations may however not be necessary as there are already existing mining and mineral-related laws, *viz*. the *Mineral Development Act 1994, Act 525*, and the relevant State Mining Enactments, both enforced by JMG. However, guidelines may need to be developed specifically for REs mining); and
c) To promote investment, from both local and international sources, in mining, extraction and processing of REs.

The mined and processed HREE metals shall be kept as our own strategic metal stocks for developing the indigenous RE-based and RE-enabled high-tech industries.

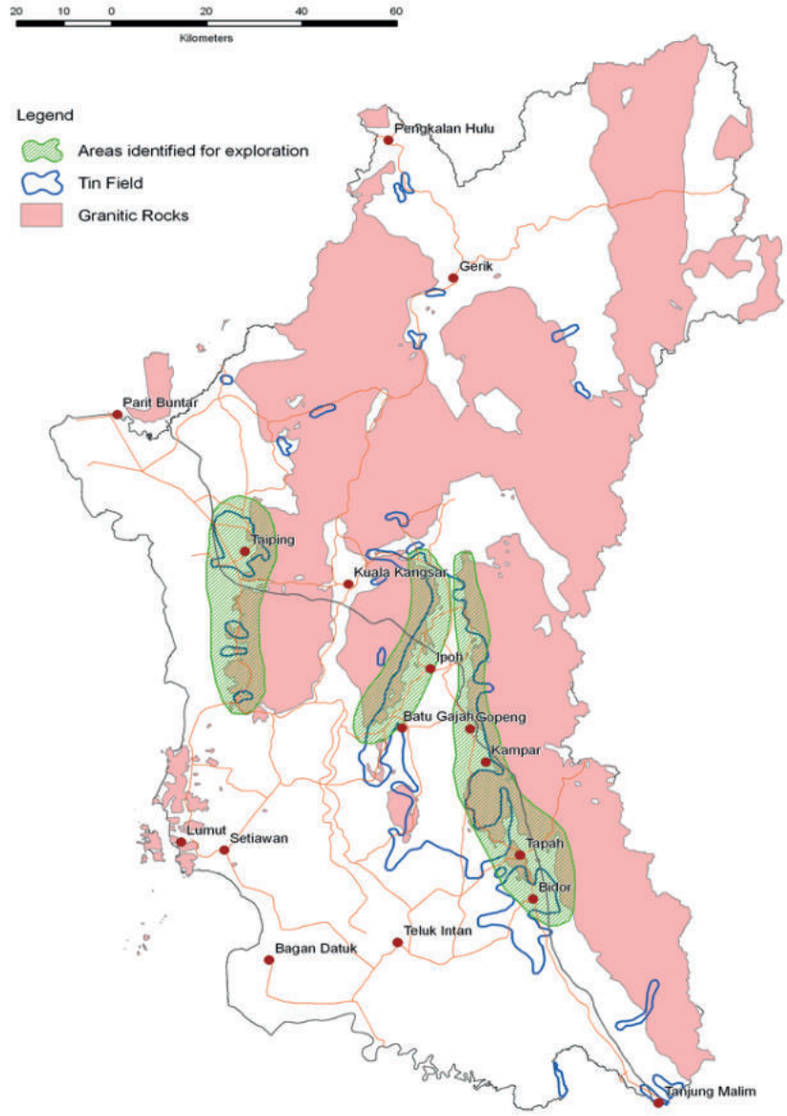

Figure 1. Areas identified for exploration of Rare Earth Element-hosting ion adsorption clay deposits in Perak.

THE LIKELY EXPECTED OUTCOME

If it is found that Malaysia does have "economical and minable reserves of HREEs", the expected desired outcomes are:

(a). To become a regional manufacturing center for RE-based and RE-enabled industries (such as industries manufacturing the following, among others:

(i) REs-based magnets for compact high-performance motors in hard disks, vehicles and hybrid and electric cars, wind turbines and compact speakers in hand-held gadgets and devices;

(ii). Production of fluorescent light bulbs involving phosphors made from REEs such as terbium, europium and yttrium (Malaysia currently has some lighting manufacturing plants with the major ones being operated by world industry leaders, such as Osram and Philips Lumileds);

(iii). Development of fluid catalytic cracking (FCC) catalyst manufacturing industry. FCC is a key process in petroleum refineries. With Malaysia's own FCC plant here, the nation would also at the same time have foreign exchange savings from importing FCCs now; and

(iv). Production of polishing powders as Malaysia has some industries that use substantial amount of high-precision polishing powder, for example, wafer processing, solar cell manufacturing, glass lens production plants.

(b). To become a regional center for the R&D on RE-based technology and products,
(c). To become a strategic location in the region for FDI to relocate their high-tech R&D and manufacturing activities, and
(d). To contribute to achieving the status of high-income nation through the strong economic multiplying effects created by the RE-related industries.

THE VARIOUS STAKEHOLDERS AND THEIR ROLES TO ACHIEVE THE EXPECTED OUTCOME

In ensuring that the expected outcomes are achieved, there should be a successful synergistic interaction between three major stakeholders, that is, the Government, the industries and, finally, society.

(a). The Government should play the lead role in implementing the Blueprint through:
  (i). Initiating early engagement with the relevant industries to establish REs-based industries in Malaysia;
  (ii). Engaging with members of the general society, including individuals and NGOs, on awareness matters concerning REs, their uses and addressing any issues raised by the public but at the same time managing effectively the misinformation surrounding REs through regular science-based and fact-based briefings;
  (iii). Initiating G-to-G collaboration programmes with China and Japan on REs technologies; and
  (iv). Having the REs sector pronounced as an NKEA.

(b). Malaysian Industries should play their role in investing in all three sectors, that is, in the three sectors as follows:
  (i) Upstream sector by undertaking a detailed exploration and economic assessment of the REs occurrence identified by the Government in Perak and elsewhere;
  (ii) Mid-stream sector by undertaking processing of REs concentrates sourced from mines developed in (i) above. This undertaking should preferably be made with expert technology partners from overseas with the necessary technical know-how to produce high-purity REs oxides (REOs), which can be sold, or the REOs can be converted REs metals which can be sold to the relevant industries in the downstream sector; and
  (iii) Downstream sector by investing in industries manufacturing magnets, phosphors, FCCs etc. Again, this could be undertaken with the relevant technology partners from overseas [Some repetition in (i) and (iii)].
  In undertaking all the above activities, industry players should ensure that their ventures are all sustainably managed without undue damage to the environment and ensuring safety to the workers, all in line with existing laws and regulations.

(c). Civil society has an important role to play in:
  (i) Ensuring that all safety, health and environmental matters concerning not just REs industries but equally all other industries are carefully monitored in addition to the Government's monitoring agencies taking into consideration that social perceptions of risk at the site level need to be balanced with broader national trajectory towards sustainable technology development in determining the social sustainability of the REs sector; and
  (ii) Understanding that REs development can be a major contribution towards developing a "green economy". Towards this end, the industrial park in Gebeng had made this case in its branding of the initiative as part of national planning effort towards sustainability; and
  (iii) Understanding and accepting that social perceptions of risk at the site level thus need to be balanced with broader national trajectory towards sustainable technology development in determining the social sustainability of the REs sector.

ISSUES AND RISKS

Impact on Society and Environment

Every industry has its risks and will impact on society and environment if measures are not taken from early on in the conceptual stage to address these risks, in other words, all industries have risks but it is how these risks are managed that is key to ensuring acceptance by society of any particular industry.

Given the complexity of REs supply from mines to markets and the potential for a "cradle to cradle" circular economy approach, the sector requires a deliberate and detailed monitoring system which should be adaptive to technological changes and strict enforcement of the relevant laws and regulations. In particular, the following four areas deserve prioritization for monitoring and enforcement:

(i). Radiation monitoring — although REs in ion adsorption clays do not contain thorium or uranium elements, nevertheless to allay public perceptions, radiation monitoring should be undertaken at the mining and processing stages.

(ii). Environmental monitoring — of REs facilities is similar to most large industrial operations. The use of complex organic and inorganic reagents in processing requires diligence in the waste water treatment system working and having secondary containment in case of failure.

(iii). Safety — monitoring of safety considerations at REs site follows protocols similar to other industrial establishment in which solvent extraction, electrolytic processes and infrastructure for piping of high intensity chemicals are used. Safety at sites is largely dependent on regulatory compliance and enforcement and RE processing sites can occur in close proximity to human habitation as long as there is stringent safety enforcement.

(iv). Health — much of the public health concerns around REs emanate from concerns around thorium-containing wastes as a source of radiation. On-going health monitoring must remain an important part of the overall community engagement plan for the mining and processing sites, as is being undertaken at the LAMP site, particularly since so much of the environmental conflict has emanated from perceptions of what constitutes an "acceptable dose" of radiation. The public health data can render such arguments redundant if effectively demonstrated that there is no health impact around the plant.

In addition, given the lack of history of public engagement with regards to the LAMP facility as there was an underestimation of the level of resistance from residents and the awakening of fervent environmentalism (for example, there was spread of misinformation about the site not being permitted in Australia for environmental reasons), a proactive policy of public engagement should be adopted routinely. Some lessons of how to approach public engagement in this particularly polarized context can be learned from the Republic of Korea.

Global Supply and Demand

Demand data shows that more than 80% of the demand for RE mineral concentrates comes from within China where its huge RE separation, refining, purification, metal making, and component making industries absorb the RE mineral concentrates as raw materials. The most important thing to note is that China's demand for heavy REs is larger than its current production of heavy REs, mainly due to the dramatic rise of environmentalism in China. China, the only significant producer of heavy REs, is now faced with a government-supported crackdown on its "leach, exhaust the deposit, and abandon the operation" methods of extracting heavy REs and yttrium from the very low grade, but radiation-free, ion adsorption clays in southern China's Sichuan and Jiangxi provinces. The total disregard for safety, health, and the environment has been the only thing allowing the Chinese to produce heavy REs. This era of production without regard to social or environmental costs has now already ended in China. This means that for the first time since the heavy REs became core technology metals:

1. China cannot produce enough heavy REs to maintain the growth in domestic demand,
2. China, having no hard rock deposits of heavy REs, must for the first time seek such materials outside of China although the country has large reserves of ion adsorption clays; and
3. It is pertinent to note that there are also ion adsorption clays outside of China in places that include Vietnam, Thailand, Cambodia, Malaysia and the Indonesian archipelago. These clays can be worked safely and in an environmentally friendly way to avoid the pitfalls that China went through.

The gap between heavy RE supply and the growth of the demand for them is a new opportunity for the "Rest-of-the-World" (ROW) heavy RE producers, because for the first time they have attracted Chinese investors. The ROW hard rock and ion adsorption clay deposits from which heavy REs could be extracted commercially present a conundrum: It will not be economical to work either hard rock or ion adsorption clays outside of China if the focus is on producing just mixed concentrates of RE minerals.

It can only become economical if value is added to the concentrates by taking them downstream to fabricated products suitable for making RE enabled devices. But if that is done, it will be more economical for end-users to utilize the fabricated forms of the REs right where they are being produced. This is the Chinese RE industry's primary fear; the fear that a total RE supply chain will be constructed outside of China that enables the mass production of REs-enabled consumer, industrial, and military devices more cheaply than can be done in China and simultaneously out of the control of the Chinese RE industry or Government.

In terms of supply, today, almost all of the supply of all of the REs and also of yttrium now comes from the People's Republic of China. In China, the light REs are mostly produced as by-products of iron mining in Inner Mongolia. Thus the global supply of light REs is underwritten and virtually subsidized by the massive Chinese iron ore mining industry.

It has been reported that the Inner Mongolia Autonomous Region of China could supply the entire world's demand for light REs indefinitely. The only reason therefore to produce light REs outside of China is to insure security of supply. Therefore, any producer of light REs outside of China must have a plan to utilize that production, or face a perilous competition from what must certainly be the world's lowest cost producer of light REs.

The issue in the global REs' markets is the security of supply of the heavy REs. This cannot be achieved unless the ROW produces and processes heavy REs. This is again where even China has a problem. Limited resources and environmental remediation are challenges right now to continued export from China of the heavy REs. It is unlikely that the Chinese would continue to export HREEs that current stocks of which are running short in China.

There are just a small handful of RE ventures in development at this time (that is, early 2014) outside of China that have any chance of ever going into the production of the mid- and heavy REs. Even if they could today produce RE mineral concentrates economically, there would be today no place at all for such concentrates to be processed into the fabricated forms necessary for the mass production of consumer, industrial and military high-tech RE-enabled devices. This, the creation of a downstream total RE supply chain, outside of China, is the opportunity for Malaysia. The creation of the first processing steps alone would make the development of non-Chinese mid- and heavy- RE mineral concentrates much more likely to be economical. A Malaysian total RE supply chain would attract investment globally even without being anchored in a domestic mining industry. But with the availability of its own local resource of heavy REs from ion adsorption clays, Malaysia would be in a stronger position to develop the downstream total RE supply chain.

Technology

In the upstream sector, Malaysia has the capability to undertake mining of alluvial resources (if it is found that ion adsorption clays have economic potential to be mined). However, it may be necessary to procure technical assistance from either the Chinese or the Japanese to undertake detailed exploration, using various technologies as well as determining the economic minability of the resource. In undertaking mining, as mentioned earlier, the environmental and safety aspects need to be always in the forefront of companies awarded mining concessions by the respective states.

In the midstream sector, technical assistance may also be needed in processing the ion adsorption clay resource, from the initial concentration and separation of the REEs to the production of REE metals/alloys.

In the downstream sector, there may be issues of intellectual proprietary rights in the manufacture of magnets, lighting phosphors or of catalysts. It may be necessary to invite companies owning the IPs to invest in Malaysia in these manufacturing areas, possibly with Malaysian partners.

Forecasted Reserves

As mentioned earlier, Malaysia was reported to have some 30 000 tonnes to 43 000 tonnes respectively of REs mineral reserves. The reserve figures for Malaysia mentioned above should be taken with caution as the basis for arriving at those figures was never provided. The mineral reserves mentioned are of monazite and xenotime, two RE-containing minerals, recovered as by-products of tin mining. These two minerals contain the much sought-after HREEs but they also contain thorium and uranium. With today's separation technology, these two elements can be safely removed and stored for future use as energy fuels as being practiced in India.

On reserves of ion adsorption clays, Malaysia has yet to begin detailed exploration of the resource. Although areas in Perak have been identified, a nation-wide exploration survey should be undertaken by the Government using the knowledge of the area's geology as the initial indicator. The MGD has the necessary geological information and is in a position to undertake such a survey.

Globally, to date, China has the world's largest known reserves of REs deposits. Elsewhere, many companies are exploring for REs deposits in Alaska, Australia, Africa, Canada, Greenland, Sweden and the USA. The Technology Metals Research (TMR), an on-line site which provides information on REs resources globally and maintains the TMR Advanced Rare Earths Index, reported that, to date (end of January 2014), the Index consists of 57 RE mineral resources, associated with 51 advanced RE projects and 48 different companies, located in 34 different regions within 16 different countries. Outside of China, only two companies are currently mining the resource, that is, MolyCorp in the USA and Lynas Corp., in Mount Weld, Australia.

Available Expertise

In the upstream sector, Malaysia has the necessary expertise in exploring and mining but as ion adsorption clays is a new area for REs exploration; we may therefore need to seek technical assistance from the Chinese or Japanese on a G-to-G basis. In the mid-stream sector, where processing of the resource is undertaken, again we may need to seek technical assistance from the Chinese or Japanese. However, some Americans have also the necessary expertise in processing of REs-containing ores. There may also be experts in this upstream sector from South Korea and France.

In the downstream sector, Malaysians would initially need the expertise of international companies which own the IPs of RE-bearing items before they can venture on their own to manufacture these items.

Research and Development

There is much R&D that would need to be undertaken in the three sectors of the REs industry. There are institutions in the country that have the necessary expertise to undertake the R&D, among them, are the Minerals Research Centre, the Malaysian Nuclear Agency and the various local universities with Universiti Malaysia Pahang's Rare Earths Research Centre leading the way. However, some specialized equipment for REs analyses may need to be purchased.

FINANCIAL/HUMAN CAPITAL AND TECHNOLOGY INVESTMENT

There is as yet no exploration or mining for REs undertaken in the country and, as such, there is very little information available locally or even globally on the financial/human capital and technology investments.

As a start, it is proposed that the Government invite investors, both local and foreign, to participate in the REs industry in the country. There is however one area where the Government would need to invest initially and that is in the area of REs exploration nation-wide.

Upstream Sector

It is suggested that the Government invest some RM10 million to undertake exploration for REs in ion adsorption clays in Perak. The allocation, to be given to NRE/MGD, will be used for undertaking reconnaissance field investigation, involving soil profile sampling and determination of pattern of REE distribution along the profile. Comparisons could be made with REE distribution patterns obtained from studies already done elsewhere in the region.

MGD would be the most appropriate agency to undertake this type of investigation as they have the necessary man-power with the basic geological and scientific foundation. The allocation would cover the costs for such investigations including the purchase of appropriate equipment for analyzing the REEs. From the reconnaissance field investigation, areas with potential could be identified for follow-up investigation. The follow-up investigation would involve closer sampling and delineation of anomalous areas and horizons with high concentrations of REEs. The anomalous areas delineated could be investigated in more detail, including conducting excavation for test leaching and evaluation of extractability of the REEs. An assessment of the possible reserves could then be undertaken.

Once Perak is completed and the report submitted to the Government, the Government could provide additional allocation, amounting to RM30 million, for MGD to undertake similar studies elsewhere in the country.

The involvement of MGD could be up to the stage of obtaining enough information to attract investors. The follow-up and detailed investigations could then be taken up by the private sector should the initial results prove attractive.

As mining is a state matter, the private sector, whether local or foreign, would only consider investing large sums in undertaking detailed investigations leading to mining only if they are given first refusal rights to mining as well as a fairly long mining lease of around 20 – 25 years. This is because investments by these companies, including mine closure and land rehabilitation after mining, could run into tens of millions in one lease. The investment would cover operational costs (such as mining, processing, labour, administration, energy, maintenance, shipping costs, among others, such as royalties), capital costs (such as site development, pre-production, labour, equipment, tailings dam, and others). As an example, the Bear Lodge open pit mine in Wyoming, USA, had a start-up cost of RM251 million (USD87 million) and Operating Costs amounting to RM25 000/tonne REO (USD8480/tonne REO).

Mid-stream Sector

Using Lynas Corp's investments in Malaysia as an example, it reported that, in Phase 1, the capital cost for the processing plant amounted to RM1.6 billion (AUS$539.33 million) in 2011. Phase 2's capital cost is estimated RM790 million (AUS$263.4 million). Phase 1 will result in 11 000 tonnes of REO being produced; Phase 2 will ramp up the production to 22 000 tonnes REO. With such high costs and the expertise needed, foreign companies can be invited to invest here either as partners with local companies or solely.

The processing here by Lynas is only to produce high-purity REOs for sale to buyers overseas. A further step that would need to be taken is to establish plants to manufacture RE metals from the REOs. It is these metals, which fetch a very high price when compared to the REOs, and they are used in many high-tech and green-tech industries. Some of the well known companies are Apple, Samsung, GE, Boeing, Air Bus and Toyota to name a few. There is currently no information available on the capital and operational costs of establishing such a plant here. However, this is where G-to-G consultations with China may help as the Baotou Rare Earths Research Institute has established such facilities in Baotou.

Downstream Sector

The required financial/human capital and technology investment for downstream industries would depend very much on the types of manufacturing industries to be established. The market is vast for the major end uses for RE elements, such as for automotive catalytic converters, fluid cracking catalysts in petroleum refining, phosphors in lighting, color television and flat panel displays (cell phones, portable DVDs, and laptops), permanent magnets and rechargeable batteries for hybrid and electric vehicles, generators for wind turbines, as well as for medical devices. There are in addition defense applications, such as jet fighter engines, missile guidance systems, anti-missile defense, space-based satellites and communication systems. For each of the industries, investments can run into hundreds of million ringgit. Malaysia would need to identify its niche areas to invite the relevant investors.

In an initial assessment by the ASM, the expected minimal contributions of the REs (REs) industry to the national economy in terms of FDI, GDP and estimated employment are 2.4% (RM1500 billion), 1% (RM 10 137 billion) and 0.04% (5000 jobs per annum) respectively by year 2020.

THE ACTION PLANS—IMMEDIATE, SHORT- AND LONG-TERM PLANS

The Blueprint provides detailed Road Maps for each of the three Sectors for implementation as follows:

Upstream Sector

In the Upstream Sector, 5 Road Maps have been developed, focusing on four types of resources and the R&D work to complement the development of the identified potential resources. The five Road Maps are:
Road Map No. 1 — On-shore alluvial xenotime and monazite
Road Map No. 2 — REE-hosted ion adsorption clays
Road Map No. 3 — RE potential in off-shore marine sediments
Road Map No. 4 — RE minerals in primary (hard rock) deposits; and
Road Map No. 5 — R&D in the upstream RE sector.

In the immediate term (within 2014 – 2015), priority should be given to implementing Road Map No. 2 (REE-hosted ion adsorption clays in the Perak state) whereas in the short-term (1 – 5 years, from 2016 – 2025), the focus on ion adsorption clays can extend to other states where the geology is favorable.

In the short-term too, the implementation of Road Map 1 (on-shore alluvial xenotime and monazite), could be implemented by the relevant states, specifically Perak, Pahang and Kelantan, inviting local companies to undertake detailed exploration for tin and other associated minerals, such as, zircon, ilmenite and struverite, including xenotime and monazite, in the alluvial tracts in these states. If these companies find economically minable quantities of these minerals, the states could issue long-term mining leases to these companies.

In the short- to long-terms (6 – 15 years, up to 2030), the Government would need to implement Road Map No. 4 (RE minerals in primary (hard rock) deposits) and Road Map No. 5 (R&D in the upstream RE sector). Road Map 4 Road Map

4 is essentially focused on evaluating the possibility of extracting xenotime and monazite from tin mineralized granitic rocks and its viability to do so commercially. The most appropriate starting point is to study the quarry dust in the quarries working on the tin mineralized granites. For Road Map No. 5, the Government would need to initiate investigations RE-related R&D activities (the proposed list is given in the Blueprint).

Finally, in the long-term, for Road Map No. 3 (RE Potential in Off-shore Marine Sediments), the Government (both Federal and State) could offer near off-shore marine areas to the private sector for exploration of RE-bearing minerals. It is important that strict environmental regulations be imposed and enforced on these companies when they undertake the prospecting (and, later, mining).

All of the above Road Maps would need to be co-ordinated and implemented by the NRE. Where mining is concerned, the Ministry would need to work with the relevant state governments. As allocations are needed to implement the activities, the Ministry of Finance is an important player.

Mid-stream Sector

As mentioned earlier, the midstream sector in the REs industry consists of activities ranging from the cracking of REs minerals into REOs down to the production of metals and alloys.

Although the processing technologies for the midstream sector are fairly well known, gaps do still occur in "cracking" and processing technologies, especially in ensuring that:

(i). Newer technologies are more environment-friendly and resource-efficient; and
(ii). The necessary human capital to support this sector of the industry is available.

In this respect therefore, the Road Maps for the mid-stream sector should focus on research and education (both in the vocational/technical and tertiary levels) in the immediate- to long-terms (up to 2030).

The areas of research which can be explored include:

- 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; and
- Sustainability.

As for education, important areas to be included in the curriculum and syllabus of the tertiary education are:

- Solid chemistry/ Properties
- Combination of different ore materials
- Urban Mining (Recycling)
- RE chemistry
- Advancement in process technology
- Unit Operations; and
- Separation technology.

In addition, the study of chemistry of REs should be included to strengthen the fundamentals. These include fundamental chemistry, molecular chemistry and engineering chemistry.

To strengthen research and education in REs, and make it relevant to industry, supporting infrastructure is needed. This includes establishment of instrumentation relevant to RE midstream applications, pilot plant sized separation equipments and analytical instruments such as:

- X-Ray Diffraction (XRD) — a tool used for determining the atomic and molecular structure of a crystal
- X-Ray Fluorescence (XRF) — is widely used for elemental analysis and chemical analysis
- Inductively Coupled Plasma Mass Spectrometer (ICP MS) — an analytical technique for determining chemical elements in samples, particularly for REEs; and
- Radioactivity detection sensors.

All of the above Road-Maps would need to be co-ordinated and implemented by the Ministries of Education (for Secondary and Tertiary levels) and Human Resource (for vocational/technical level). As allocations are needed to implement the activities, the Ministry of Finance should also be involved in decision-making.

Downstream Sector

Based on the overview and analyses of the downstream sector of the RE industry (as detailed in the Appendix of the Blueprint), it was concluded that Malaysia has certain advantages in some areas of REs applications, such as the manufacture of RE magnets, batteries, lightings, catalysts, glass, lenses and polishing powder.

In order to set up these industries, the following issues need to be addressed in the immediate- to long-term:

(i). Technology — the know-how to manufacture the products;
(ii). Funding — the financial resources to establish the facilities and operations; and
(iii). Human capital — the manpower with the necessary knowledge to support the operations.

There are other factors such as raw materials, infrastructure, environment, etc. that need to be considered as well. Of all these, the technology and know-how factor appears to be the weakest aspect of Malaysia for venturing into REs-related downstream industry.

To address the problem, Malaysia should adopt the following strategic approaches:

(i). Attract more FDI to address financial resource needs and more importantly, the need for technology and know-how in high-tech industry;
(ii). Build up the human capital (skilled workforce) relevant to the industry; and
(iii). Encourage and support more R&D activities to develop new technology and develop research capabilities (including manpower) for the industry especially moving up the value chain.

All of the above Road-Maps would need to be co-ordinated and implemented by the Ministries of International Trade and Industry, Education (for Secondary and Tertiary levels), Human Resource (for vocational/technical level). As allocations are needed to implement the activities, the Ministry of Finance should also be involved in decision-making.

In undertaking the implementation of all the above Road-Maps, it is proposed that an ICMTM be established to play the roles pertaining to advanced and critical materials and the relevant industry sectors. Considering the relevance of ICMTM to the development of advanced and critical materials-based industries, it is important that the institute be structured and organized such that it is industry-driven and with at least half of its board consisting of members from the industry.

Among the roles that ICMTM could play are:

(i). Design of direction, strategy and national master plan for the relevant industry sectors especially in technology, manpower, infrastructure development;
(ii). Sourcing and management of funding and other resources and infrastructure for R&D in areas related to the industry sectors;
(iii). Bridging and co-ordination between industry and universities in R&D and human resource development relevant to the industry sectors;
(iv). Spearheading major R&D research programmes related to the industry sectors in collaboration with various industry players and universities, and
(v). Setting up and managing major research facilities and equipment which are open for access by industry and universities.

There should be Government research funding allocated for R&D in advanced and critical materials and such funding should be made available and managed through ICMTM. Besides that, ICMTM should also work with the industry on funding from industry in some key research areas which are of interest to specific industry players.

ICMTM should also play the role as the bridge between industry and universities in human resource development for the industry by ensuring universities and polytechnics are well aware of and take necessary actions on the human power needs of industry. A master plan on human development for the industry which includes projection of future needs should be formulated and reviewed by ICMTM continuously.

Climate Science and Technology for Disaster Prevention

J.J. Pereira[1], M.I.H. Reza[1] and J. Hunt[2]

The Asian Network on Climate Science and Technology (ANCST), co-ordinated bythe Southeast Asia Disaster Prevention Research Initiative of Universiti Kebangsaan Malaysia (SEADPRI-UKM), with the support from the Cambridge Malaysian Education and Development Trust in Association with the Malaysian Commonwealth Studies Centre of Trinity College, Cambridge, organised its inaugural technical meeting on *Climate Science and Technology for Disaster Prevention* on 20 November 2013 at Putrajaya, Malaysia. An ANCST Symposium was organised, and it was a special invited session, held in conjunction with the International Conference on *Extended Mega Urban Regions: The Changing Face of Southeast Asia and the World*, organised by the Institute for Environment and Development of UKM and partners, from 19–21 November 2013.

The ANCST Symposium was co-organised by University of Cambridge; City University of Hong Kong; Indian Institute of Science, Bangalore; Advisory Committee on Protection of the Sea; Academy of Sciences Malaysia; and SEADPRI–UKM.

The programme comprised a Key Note Address delivered by Emeritus Prof Lord Julian Hunt entitled *Climatic and Urban Effects on Hazards and Impacts* (Malaysian Commonwealth Studies Centre Cambridge and University College London) and seven oral presentations from local and international experts, as follows:

- Research Needs for the Asian Region to Address Climate Change by Prof Johnny C.L. Chan, *City University of Hong Kong*
- Tackling the Impact of Climate Change in South Asia by Prof J. Srinivasan, *Indian Institute of Science, Bangalore*
- Predictability of the Northeast Monsoon Cold Surges over the Malaysian Region by Kumarenthiran Subramaniam, *Malaysian Meteorological Department*
- Tropical Soils and Flood Management—New Applications for Old Science? by Dr S. Paramanathan, *Param Agricultural Soil Services, Malaysia*
- Geohazard Mapping and Assessment—Tools to Reduce Risks of Climate Extremes? by Dato' Zakaria Mohamad, *Minerals and Geoscience Department Malaysia*
- Groundwater Salinization—An Emerging Slow Onset Risk? by Dr Saim Suratman, *National Hydraulic Research Institute of Malaysia*
- Building Climate and Disaster Resilience—A Budding ICT Market? by Tengku Mohd Azzman Shariffadeen, *Academy of Sciences Malaysia*

The presentations provided insight on science and technology needs for dealing with new challenges of risk management and climate adaptation for the extended mega urban region. Selected highlights are briefly described below.

Major modes of climate variability such as El Nino—Southern Oscillation, Indian Ocean Dipole and Madden-Julian Oscillation is expected to affect anthropogenic warming and thus impact Southeast Asia, compared to East and South Asia. The rapid growth of cities in conjunction with the increase in land temperature has exacerbated the urban heat island effect. Small green spaces have been found to be more effective in ameliorating the heat effect compared to large tracts of green areas. Over the past two decades, warmer urban heat islands have been reported in Hong Kong, Shenzhen and Macau (Figure 1). There is an urgent need to address the downstream impacts of the urban heat island effect.

More intense rain associated with typhoon is expected with climate change and at landfall such heavy rain will lead to more disasters associated with flooding. Flooding is likely to be exacerbated since storm surge will be higher due to sea-

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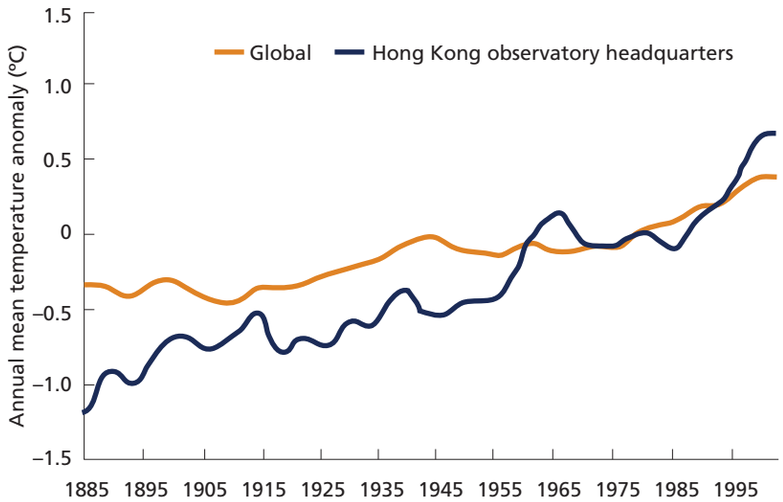
level rise. Extreme sea-level rise is more relevant than mean sea-level rise in this respect. The shrinking periods of extreme rainfall have the potential to create more hazards such as floods in low-lying areas. Intense rainfall also triggers landslides in the highlands. Short-term forecasts are getting more important to address climate extremes. There is a need to understand and be aware of the variation and return periods associated with climate extremes. However, limitations in climate data have resulted in inaccurate models and this is a challenge that should be immediately addressed.

The prognosis does not bode well for extended mega urban regions in Asia. Communities need to know if they are exposed to extreme events. For this purpose, hazards and risk maps are useful to delineate areas that require special attention to build resilience. There are cases where the property prices have dropped or insurers have pulled out or increased the premium tremendously in areas that have been identified as high risk. Such actions normally burden the low income groups. The role of government and civil society becomes important in such cases, to negotiate options based on inherent values. New approaches need to be identified in the insurance sector to help society cope with the risk of disasters. There is also a need to build local level resilience. Community-based disaster prevention actions have brought about positive outcomes in many areas such as Bangladesh and India. These actions can be replicated in other parts of Asia.

The urban heat island effect and extreme precipitation leading to flash floods and landslides are not uncommon in Malaysia, particularly in the extended mega urban area of Greater Kuala Lumpur. Flash floods and landslides are the most common disasters in the country (Figure 2). There are many challenges associated with these disasters, ranging from science to governance. It was noted that flash flood mitigation has had limited success in urban areas that are cemented and impermeable. New multidisciplinary approaches are required to address this issue. For example, subsurface geology and soil characteristics greatly influence rainwater runoff and this input can be useful for addressing the urban floods. Subsurface geology and soil characteristics also influence seepage in exposed areas which then promote the development of slip zones that lead to slope failures. Such aspects need to be carefully investigated to bring about holistic solutions.

Other issues mentioned include the need to enhance enforcement, audit drainage systems, inspect slopes and monitor groundwater resources particularly in coastal areas due to imminent water stress conditions. All the issues are also relevant to other extended mega urban regions in Asia. The role of the community as well as information and communication technology was highlighted in this respect. Crowd sourcing is an unexplored area and has great potential to organise communities that are more resilient. It can also provide information to enhance enforcement and effectiveness of technical agencies. A neutral and respected platform is required to bring together all the relevant stakeholders including the community, to mobilise science and technology for preventing disasters in a world where climate extremes become more common. The role of ANCST in providing information and facilitating research co-ordination in conjunction with national and regional platforms is crucial in this context. A quote from Albert Einstein —*Those who are in the know have the duty to act.*



(Source: Hong Kong Observatory Headquarters.)

Figure 1. The annual mean temperature anomaly of Hong Kong has been higher than the global level since the 1990s.

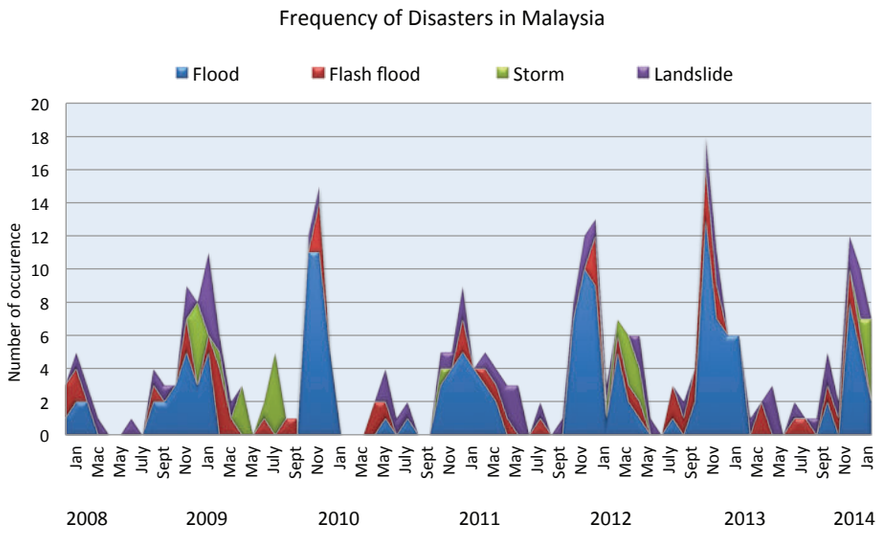


Figure 2. Frequency of flash floods, floods, landslides and storms in Malaysia as reported in major newspapers from 2008 to January 2014. (Compiled by Mohd Faizol Markom, SEADPRI–UKM.)

Crowd-funding Scientific Endeavours in Malaysia: Scientists Should Take Their Research Ideas to "The Wild"

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As the world inches slowly out of the economic recession, the government appropriation for scientific and technological endeavours has been under threat. Scientists and innovators have been struggling to get funded. In the United States alone, sequestration measures have put the future of science in limbo, with 5.1% decrease in non-defense research funding for 2013 (Martin 2013). Across OECD countries, the government's share in R&D funding decreases. Adding to the amounting financial pressures, the convoluted government bureaucracy is often cited to be one of the major stumbling blocks in the development of national S&T (Robinson 2010; Wolinsky 2010; Miller 2007; Dickson 2002). According to a 2007 USA study, scientists spend 40% of their time navigating the government bureaucracy to get grants (Scientific American 20110 .

Scientists turned to industry for financial support; however, at least in Malaysia, the trends show that industry is primarily interested in funding the development to commercialization stages of R&D. Alternative funding is available but venture capital and angel investors are more typical at the startup/seeding stage. One might argue that this funding scheme steers science from the pure pursuit of knowledge to profit-oriented venture. Thus, how can we strike a balance between these two?

Perhaps, active participation by the public at each level of R&D can be the answer. This brings us to the concept of crowd-funding. According to Belleflamme *et al*. (2013) "Crowd-funding involves an open call, mostly through the Internet, for the provision of financial resources either in the form of donation or in exchange for the future product or some form of reward to support initiatives for specific purposes". The scheme is similar to crowd-sourcing, in which the operation (in this case, investment) is outsourced to the masses (Agarwal *et al*. 2013) instead of banks or venture capitals.

In most cases the creator or innovator will co-operate with a platform to attract funders. The creator will propose a project that requires a quantum of funding and if the project appeals to the investors, the investors will then pledge a sum of money until the campaign duration elapses. When the money raised during the campaign achieves the target, the creator will receive the funding or else the money will be returned to the investors.

The latest taxonomy of the crowd-funding platforms shows most platforms provide funding from indie films to wearable technology. Among the most popular global crowd-funding platforms are *Kickstarter, RocketHub* and *SciFund Challenge*. *Kickstarter*, for example has registered on average of 12 million (Quantcast.com 2014) monthly website visits since last year. It has raised about USD1 billion for 61 711 successful projects (*KickstarterStatistics* nd). The driver behind the increasingly popular movement of collective investment such as crowd-funding can be linked to the proliferation of social networks which allow participants to share their stories and findings. This phenomenon has been leveraged by mainstream organizations such as CNN (CNN iReport nd).

Similar motivation framework can be applied in crowd-funding science and technology initiatives. Public involvement in scientific endeavours can be traced back to since the 17th century (Miller-Rushing *et al*. 2012). The advocacy of science has evolved since then. The democratization of scientific data has provided the public the opportunity to assess the impact of scientists' work. The public now is better informed, and thus is keen to participate in scientific endeavours more than ever. The popularity of scientific crowd-sourcing projects such as Galaxy Zoo and Note From Nature is the testament to that fact.

Besides contributing their thoughts and time to scientific projects, the public also has chosen to contribute with their wallet. Initially, most crowd-funding projects emphasize on prototype projects with the most successful ones hosted on Kickstarter (i.e. *Pebble SmartWatch*). As crowd-funding becomes more popular, the portfolios of crowd-funding expanded to include musical, video-game, philanthropic and even scientific research projects. Since 2011, niche crowd-funding platform that cater to R&D started to be established. Among the firsts are *SciFundChallenge*, *Petridish.org*, Experiment.

com (formerly known as *Microryza*). So far, these platforms have managed to show positive outlook of scientific crowd-funding. SciFund Challenge reported (Faulkes 2014) that the number of research projects which are fully funded has progressed. As the researchers learn to pitch their projects through blogs or online videos, the ultimate goal for crowd-sourcing becomes more apparent: Crowd-funding is not solely about monetary gain, but the promotion of transparency and instillation of public confidence in the scientific enterprise.

Information from major scientific crowd-funding platforms reveals that successful project does not have to be at a big scale, as shown by Ethan Perlstein (Figure 1). Even overlooked research topics are able to attract funding from the masses (Wheat *et al*. 2013). To date, the most successful project by the amount of money raised is Arkyd Space Telescope. This project, developed by Planetary Resources, Inc has raised USD1.5 million and has garnered 17 614 backers (Leone 2013).

In terms of policy development, United States and EU have taken the early lead in developing government regulatory support forcrowd-funding. *US Jobs Act* has allocated clauses that protect both funders and project owners, especially in equity-based crowd-funding. In 2011, *Democratization of Capital Act* was signed allowing entrepreneurs to raise investment from the masses. Under this Act, crowd-funding platforms will go through verification by Securities and Exchange Commission (SEC). Considering 1/3 of total world's crowd- funding campaign is contributed by European countries, EU has to be onboard, even so at the frontier of crowd-funding regulation. In November 2011, European Union launched Bielsko-Biela Declaration to increase the participatory financing in Small- and medium-enterprises (SMEs) or entrepreneurial projects.

At the other side of the globe, Japan has setup regulations to foster entrepreneurial economies among SMEs under the direction of "Abenomics", dubbed by the current Prime Minister Shinzo Abe. With the regulations, businesses can raise fund through online platform up to USD1 million. According to KazOhmae, the CEO of *CrowdBank*, the Japanese crowd-funding platform is expecting some 10 000 investors in 2015 (Crowd Valley Inc. 2014).

Since most of scientific researchers do not have tangible return of investment, the investment model is mostly donation-based and relies upon social returns (motivation and personal interest). One of the advantages of crowd-funding is that the donation pool is global. The success of ArduSat, a nano satellite, truly reflects the internationalization factor of crowd-funding: the crowd-funding platform is a US-based Kickstarter, the satellite maker is based at San Jose and the satellite is launched by Japanese space-vehicle. Undoubtedly, social media is a key factor in raising money through crowd-funding (Lu *et al*. 2014). Across all scientific crowd-funding platforms, there is a strong correlation between the size of social network friends and the probability of fully funded project. Thus, the project creator or researcher must be social media savvy to advertise and rally backers of their project. With all the advantages that crowd-funding can offer to the researchers, the early exposure of research ideas can be a double-edged sword. We do acknowledge the risk of exposing research ideas or even IPs to the public or competitors.

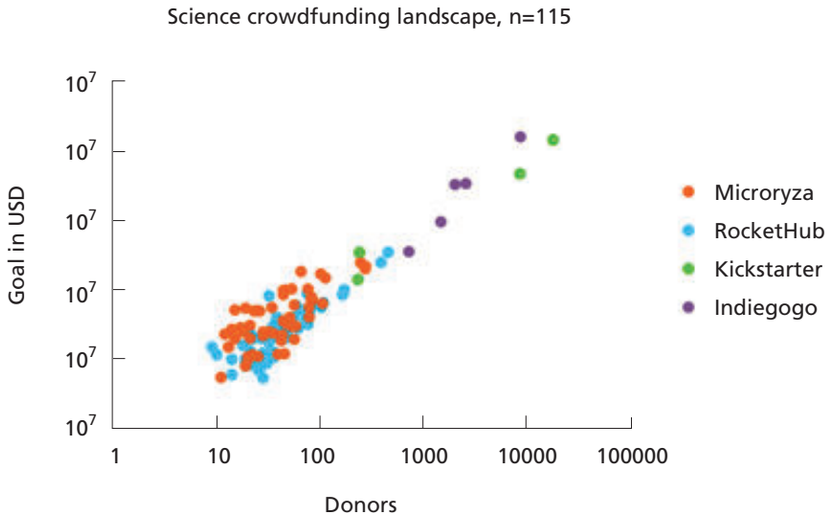

Figure 1. Science crowd-funding analysis —(EthanPerlstein.com)©

What would be the implication to Malaysian scientific fraternity? Amidst the ongoing debate that whether research funding is lacking or researchers did not come up with original ideas that warrants financial backing, Malaysian scientists should look into exploring crowd-funding. They should leverage on the distance-less factor of crowd-funding, as found by Agarwal *et al*. (2011), as long as the research proposal appeals to global masses. Finding donors and backers at the home turf, poses a huge challenge. On one hand, the public's propensity to spend is certainly positive, given the increasing balance sheet of average Malaysians. Rising household income has expanded with Malaysian household assets increased from 267% to 322% of GDP from 2002 to 2013 (Bank Negara Malaysia 2013).On the other hand, with the proliferation of Internet in Malaysia, the security of online banking still remain as the main concern among Internet banking adopters (Hong 2013).

Young Malaysian scientists indeed need some encouragement to be more entrepreneurial. A survey done by Manjit Sandhu (2011) provides a glimpse to the entrepreneurial spirit among Malaysian post-graduates; the lack of social networking, followed by the lack of resources and aversion to risk are the top three highest barriers to entrepreneurship among the post-graduates.

Even the crowd-sourcing movement in Malaysia is still nascent, especially in science. Perhaps the usage of crowd-sourcing website *Tomnod.com* in the search for the missing MH 370 flight might increase the awareness of Malaysians of the advantage of crowd-sourcing. There is a glimmer of hope, nonetheless. The stories of some students who managed to raise fund in financing their visit abroad show us that there is untapped market for the crowd-funding academic activities. This development should at least provide an indication that the crowd-funding in Malaysia can be taken to the next level.

For researchers, especially the budding ones, the diversification of financing modality is needed. But to earn the support of the masses, the researchers should learn how to develop soft skills, primarily to market and to position their research ideas. Persuasive skills should be developed along with social-media skills whereby the researchers can update their backers on Facebook, Twitter, Instagram or blogs. According to Social, Digital and Mobile Asia Study 2014, Malaysians have the highest number of Facebook friends in the world. The pool is already there. The researchers should flex their outreach muscle to rally their friends and families to fund their projects.

With the advent of the 21st century, it is time for Malaysian researchers to test their ideas "in the wild" with crowd-funding and lessen their dependence on traditional funding.

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Rethink Cutback for Research Varsities

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Spending on R&D has always been under close scrutiny. This is understandable since the expenditure on research does involve significant sums of money. Research is after all a long-term investment for the country. Unless carefully planned, research can end up with virtually no significant gains. In the 10th Malaysia Plan, more than RM2 billion were allocated for R&D in the country. Much of that money ended up in the country's higher learning institutions, mainly the universities. Those researches, especially the applied research, which do not translate into commercial gains or beneficial use by society may well be considered a waste. Unfortunately the success record for many years has not been encouraging. A very high percentage of the R&D undertaken have not reached the market place. Concerns have therefore been raised as to the wisdom of allocating funding for research in the country.

However, with the formalisation of the research university concept a few years ago, things started to look up. Backed with reasonably adequate funding support, coupled with improved management autonomy, a recent assessment shows that the five research universities in the country have performed extremely well. Publications in many highly cited internationally refereed journals were significantly up. Patent acceptance has also seen much improvement. So much so that all the research universities have confidently declared that they are destined for world class performance in a matter of years. In other words, they will soon be among the top world universities in the global ranking. Each year, every one of the five universities received RM100 million funding for R&D.

But in 2014, though earlier promised the usual RM100 million, all the five universities were jolted by the news that their allocation would be reduced by half. Later, there were rumours that the cutback would be limited to only a quarter. This however could not be confirmed. Whatever it is, the reduction would signficantly derail the long-term plan that all the five have worked out for their universities. Some post-graduate research would have to be aborted. Not to mention the many post-doctorates and the research assistantships that the universities have engaged. Once such talents leave for other pastures, the country's research pool of human capital will be lost. A more concerned impact will be the growing ridicule over a career in research. As it is, the interest among students in science has yet to pick up momentum.

Yet the country wants to increase the number of research scientists and engineers, RSEs, to help support the nation's innovation aspirations. By 2020, the plan is to have at least 100 RSEs per 10 000 workforce. Developed countries have many more. Our ASEAN neighbours are agressively pursuing programmes to increase their research talent. If we are not careful, we will soon be trailing behind Indonesia, Vietnam and Thailand. This does not augur well for the nation's competitiveness, even within the region. It is already a widely accepted fact that in the coming years, nations which fail to measure up in terms of innovation have much to lose in the global competition. Furthermore, a country may well allocate a lot of money for research, but nothing much will happen without the availability of good research talents.

The Academy of Science Malaysia (ASM), has been actively lobbying for continued support for science and innovation. This is because from the Academy's Megascience studies assessing the country's future, without adequate talent in science, we will have difficulties mitigating the business risks that will emerge. In addition we will not be in a position to capture many technology-driven opportunities that are sure to dominate future business. These will include new businesses in the bioeconomy such as new therapeutic drugs and vaccines, as well as the emerging opportunities in the green economy. Even our dreams to venture into new businesses based on nanotechnology will simply vanish. We would like to appeal for a rethinking of the announced cutback for research universities. By sustaining the funding support, we may not reap the benefits now, but we will definitely harvest the rewards many times over in the coming years. This has been demonstrated time and again by nations which invest heavily in science and research!

[1]Fellow, Academy of Sciences Malaysia

Emeritus Prof Dato' Lam Sai Kit—

Pioneer in Clinical Virology in Malaysia... His research in Dengue is Recognized Worldwide; Jointly Discovered the Nipah Virus... Recipient of the 2013 Merdeka Award; Joint Recipient of the Prince Mahidol Award (2001) for Public Health with Barry Marshall (Nobel Prize for Physiology or Medicine in 2005)

Prof Lam Sai Kit

Emeritus Prof Lam Sai Kit, was born in Ipoh, Perak and received his early education at the Anglo Chinese School in Ipoh. Upon completion of his secondary education in 1957, he set sail for Australia, to pursue a BSc. degree, graduating in 1960 from the University of Western Australia.This was quickly followed by an MSc degree from the University of Queensland in 1962 where he was initiated into medical research. Later, while pursuing his Doctorate from the Australian National University his PhD research on viruses and wildlife in Papua New Guinea further stimulated his interest in the field of epidemiology.

Setting Foot into University of Malaya

Having survived the tribal lifestyle among the natives of Papua New Guinea, Prof Lam soon became the target of a different sort of headhunter: Prof T. J. Danaraj, then Foundation Dean and Professor to the University of Malaya's (UM) Faculty of Medicine, invited him to return—even before he had completed his PhD. Prof Danaraj wanted someone to help set up the new virology unit at the faculty.

"I enjoyed the challenge of working in new areas; virology was beginning to take off after it became possible to grow viruses in the laboratory," Prof Lam recalls, and credits Australian lecturers with initiating him into this new and exciting field.

In 1966, Prof Lam returned to find only a small floor space marked for virology—no lab, no equipment, no manpower. He recalls that their first piece of equipment—a large egg incubator for growing influenza viruses—served him well for 20 years. It was truly an effort started and built up from scratch. As such, Prof Lam was given a free hand to develop and provide a diagnostic service in clinical virology, the first in the country.

Over the years, he would become Professor and Chair of Medical Microbiology at the Faculty of Medicine and Senior Consultant Virologist at the University of Malaya Medical Centre, helping to train and mould thousands of graduates in medicine, dentistry, pharmacy, public health, microbiology, pathology and other medical sciences.

International Legacy

While firmly rooted in the efforts of nation building, with his feet firmly planted in Malaysian soil, Prof Lam's eyes were on more distant horizons.

Early in his career, he decided to conduct research in diseases with an international presence, i.e. those that did not recognize borders. Influenza research in the late 1960s led to the designation of UM's Department of Medical Microbiology as a World Health Organization (WHO) National Influenza Centre, back in 1969, at the height of the global pandemic of Hong Kong Flu.

"My guiding principle in life is to share my expertise and knowledge through the internationalizing of health research," he says.

In the 1970s, Prof Lam enlisted a team of paediatricians, epidemiologists, virologists, immunologists and molecular biologists to undertake the study of dengue. At that time, little research was being conducted even though the region was badly affected by the disease. In 1982, the department was designated the WHO Collaborating Centre for Reference and Research on Dengue Fever and Dengue Haemorrhagic Fever, and remains so to this day.

In the years following, Prof Lam focused on new tools to diagnose viral infections. He initiated rapid viral diagnosis via an in-house ELISA technique which allowed dengue infection to be diagnosed within the same day. These achievements led the Department being designated a WHO National Center for Rapid Viral Diagnosis in 1980 and a two-year stint in Geneva for Prof Lam. He said that working for WHO opened his eyes. Instead of thinking of national or even regional health issues, he started to think of global health issues. During this time, he conducted workshops in developing countries to promote new methods of rapid viral diagnosis of respiratory diseases as well as rotavirus diarrhoea, both of which afflict young children. These workshops, and the introduction of rapid techniques, were carried out in Thailand, Vietnam, (then) Burma, Mexico and Africa. He, along with his good friend, Prof John Mackenzie in Perth, Australia, founded the Asia Pacific Society for Medical Virology in 1982 which now has 600 members from over 40 countries.

The Great Discoveries of the Nineties

Prof Lam's key interest has always been in emerging diseases, which he believes to be at the frontier of medical research. Though they are only just emerging on a larger scale, they are by no means new. "Some of these are old diseases, having existed for ten or twenty years, but we did not pick them up before because we did not have the technology."

His involvement in the WHO Programme on Emerging Infectious Diseases since 1990 has had tremendous impact and significance to public health. Some of these include the discovery of EV71 (Enterovirus 71) in 1997 as a cause of fatal encephalitis during the Hand, Foot and Mouth Disease outbreak; the discovery of Chikungunya virus (believed to be introduced by migrant populations) as a cause of polyarthritis in 1999; and the initiation of surveillance for viral infections like rotavirus diarrhoea, human and veterinary influenza.

His forty years of research into dengue has led to the reduction of morbidity and mortality of the disease, via a better understanding of its immunopathogenesis, early diagnosis and medical intervention, and an early warning system (to virus seasonality and changes), which has helped in predicting severe outbreaks. His research in dengue is recognized worldwide. In 2010 he was appointed Chairman of the Asia-Pacific Dengue Vaccine to Vaccination Steering Committee, which aims to rapidly introducethe dengue vaccination to dengue-endemic countries when it becomes commercially available, hopefully by 2015.

The 1998 discovery of Nipah virus by the Merdeka Award-winning UM team (of which he was a part) as a cause of viral encephalitis among pig farmers received worldwide attention and vast media coverage from news channels like the CNN, NHK, BBC and the ABC. The discovery led to the culling of pigs as a measure of preventing it from spreading out of Malaysia, eliminating the disease in the country and aiding the recovery of a billion-ringgit industry. Through his international connections he was able to activate international collaboration from the WHO, the CDC in Atlanta, USA, and the Australian Animal Health Laboratory in Geelong, Australia.

But technology is only a tool, Prof Lam cautions; vigilance is the word. "We must adopt new technologies in our fight against new and emerging diseases, not only in disease surveillance, but also in prevention and control to prevent worsening situations. Living in a borderless world will render us all the more vulnerable to exotic micro-organisms and diseases."

At the same time, this 'borderless world' has opened new frontiers for collaboration as well. "I connect all the APSMV members just by a click or two. I can get all the pictures and journals I want. What is the point of having an office?" he muses.

In spite of the immense social impact of these great discoveries, Prof Lam feels that there isn't enough public and professional interest in these medical research disciplines. "It is not a glamorous job," he says. "That is probably why a lot of doctors prefer not to specialize in microbiology or even pathology!" He hopes that more doctors will consider becoming clinical microbiologists. "Those who have science degrees, like me, lack the medical background."

Recognition and Accolades

Prof Lam's work over the years has garnered recognition, both locally and abroad.

In 2001, he was the joint recipient of the Prince Mahidol Award for Public Health with Prof Barry Marshall of Perth, Australia, who went on to receive the Nobel Prize for Physiology or Medicine in 2005. He was the recipient, with the Faculty of Medicine's Department of Medical Microbiology, of the Japan Nikkei Asia Prize for Technological Innovation in 2002.

In 2004, he was named an Emeritus Prof by the University of Malaya, and in 2005 he gained a French knighthood, being made a Knight of the National Order of Merit (*Chevalier de l'Ordre National du Merite*).

He has a formidable portfolio of over 240 scientific publications, nearly 80 of which are in ISI/WoS journals, including some of the top scientific journals in the world, such as Nature, *Science, The Lancet,* the *New England Journal of Medicine, and Virology*.

A Heart for Community and Family

While the ivory towers of academia are where he cut his teeth and forged his legacy, Prof Lam remains firmly grounded in the needs and concerns of the wider public.

The discoveries made over the years have saved lives through better management of patients and the prevention of epidemics and outbreaks. Even the national childhood vaccination programme was influenced by his research, leading to now-routine procedures like the rubella vaccination, rotavirus vaccination, and hepatitis immunization, to name a few.

Nonetheless, he remains cautious about the onward march of human 'progress'. "The rapid pace of life, coupled with economic affluence, has led to new health challenges, such as the 'diseases of the affluent' like diabetes and coronary heart disease. At the same time, there is a resurgence in communicable diseases like multi-drug-resistant tuberculosis."

Prof Lam is married with two grown children. There is a domestic face to this cerebral scientist: every Saturday, he accompanies his wife to the neighbourhood market.

High Impact Research and Beyond

Officially retired since 2003, Prof Lam remains active in academic circles. The pioneering spirit, a hallmark at the start of his career, endures even as he serves as Consultant to UM's High Impact Research, an initiative to transform UM's research culture towards publication in top-tier international journals.

Appointed as Consultant in 2010, his present work involves mentoring a new generation of young and highly motivated researchers, actively promoting research in UM, and helping young and newly-appointed staff to obtain research funding. HIR, while still in its nascent stages, has enjoyed disproportionate success, attracting over 100 global top universities to participate in joint research with UM as well as several Nobel Laureates.

But Prof Lam knows what it is like to work with limited financial and infrastructural resources. "Our dengue research is a good example of regional scientists working together to share virus strains, laboratory and epidemiological data, and better clinical disease management and prevention."

A strong proponent of international, regional and interdisciplinary collaboration, he remarks: "We should not be shackled by the popular belief among scientists that something is beyond us because of limited resources. Malaysia is a good example that it is possible to break the mould and become an international key player in both fundamental and applied research."

"Despite my retirement or because of my retirement, I hope to continue to play a more active and international role in medical education, promotion of public health, and the global dissemination of scientific information. When you love what you are doing, it is not work."

Prof Lam shows us that if we can do the work that must be done, and do it well, regardless of what people think of us, then, perhaps, we can be a shining light to the nation and the world. He has gone on ahead of us down this path, and beckons us forward. He may not be a towering person, physically, but like the viruses to which he has devoted his life and research career, he demonstrates that size does not matter. All that counts is the size of your heart and the might of your mind.

This is perhaps Prof Lam Sai Kit's 'highest impact' work—a legacy that will ultimately outlive him. In passing on the baton for sound research of the highest calibre, he is laying the foundation and lighting the way for future generations of researchers—and because this light is born again from generation to generation, it becomes inextinguishable.

APPENDIX

Fellowships/Honours

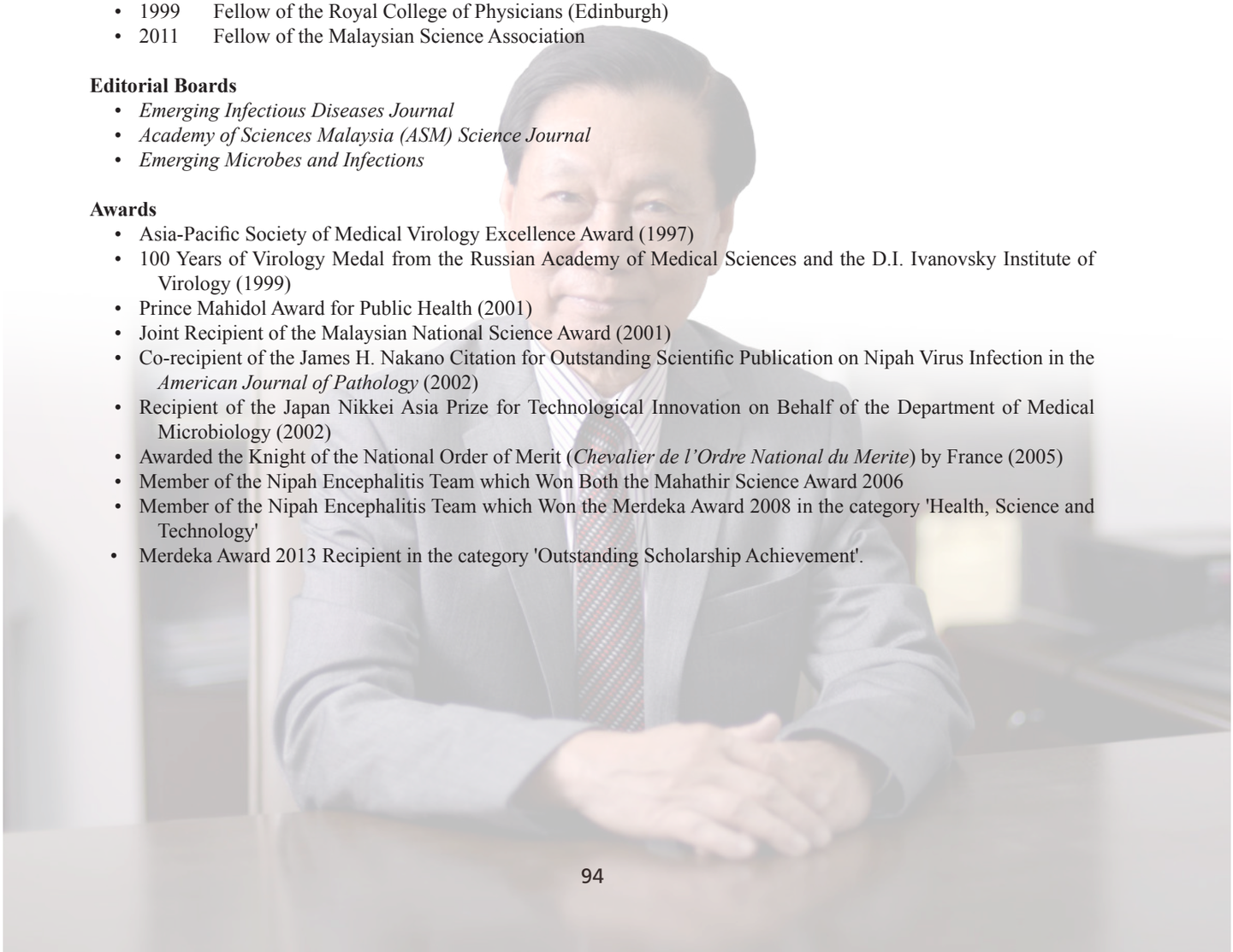
- 1991 Fellow of the Royal College of Pathologists (London)
- 1991 Honorary Professor, Institute of Microbiology and Epidemiology, Beijing, China
- 1996 Fellow of the Academy of Science, Malaysia
- 1996 Fellow of the American Academy of Microbiology
- 1996 Corresponding Fellow of the Infectious Diseases Society of America
- 1999 Fellow of the Royal College of Physicians (Edinburgh)
- 2011 Fellow of the Malaysian Science Association

Editorial Boards

- *Emerging Infectious Diseases Journal*
- *Academy of Sciences Malaysia (ASM) Science Journal*
- *Emerging Microbes and Infections*

Awards

- Asia-Pacific Society of Medical Virology Excellence Award (1997)
- 100 Years of Virology Medal from the Russian Academy of Medical Sciences and the D.I. Ivanovsky Institute of Virology (1999)
- Prince Mahidol Award for Public Health (2001)
- Joint Recipient of the Malaysian National Science Award (2001)
- Co-recipient of the James H. Nakano Citation for Outstanding Scientific Publication on Nipah Virus Infection in the *American Journal of Pathology* (2002)
- Recipient of the Japan Nikkei Asia Prize for Technological Innovation on Behalf of the Department of Medical Microbiology (2002)
- Awarded the Knight of the National Order of Merit (*Chevalier de l'Ordre National du Merite*) by France (2005)
- Member of the Nipah Encephalitis Team which Won Both the Mahathir Science Award 2006
- Member of the Nipah Encephalitis Team which Won the Merdeka Award 2008 in the category 'Health, Science and Technology'
- Merdeka Award 2013 Recipient in the category 'Outstanding Scholarship Achievement'.



Prof Halimaton Hamdan—

VC of UniMy; Pioneered Zeolites and Nanostructured Materials Research in Malaysia—Inventor of Maerogel and Winner of the 2009 Coveted Merdeka Award for Health, Science and Technology...

Prof Halimaton Hamdan

Prof Halimaton Hamdan was an academic in Universiti Teknologi Malaysia (UTM) for 31 years and successfully promoted her research and innovative activities globally. She initiated the NanoMalaysia Programme and was the Head of National Nanotechnology Directorate at the Ministry of Science, Technology and Innovation (MOSTI) in 2010–2012. She received her PhD in Physical Chemistry from University of Cambridge UK in 1989. She received her MSc degree from Marshall University, USA (1981) and BSc degree from Indiana University, USA (1979). She was the first woman professor in UTM at the age of 40. She pioneered the Zeolites and Nanostructured Materials Research in Malaysia. To date, she has led 25 research programmes and 80 projects in the field, garnering grants of more than RM13 million and over 100 journal publications. Her research is about sustainable, green and clean processes by molecular manipulation to synthesize new nanostructured materials, systems and complexes via heterogeneous catalytic reactions.

Prof Halimaton is renowned for inventing Maerogel; from rice husk, the lightest solid and best insulator known today was chosen as the product of 2008 by International Clean Energy Circle, UK. Maerogel has been patented in Malaysia and 22 other countries worldwide and is currently being commercialized through her spin-off company, Gelanggang Kencana Sdn Bhd. In addition she owns 12 patents on zeolites and mesoporous materials. Her current research include probing of new generation hybrid, chiral, bifunctional and functionalized heterogeneous catalysts, drug delivery systems, nanostructured materials, nanofibers and aerogel focused on improved efficiency in the production of alternative energy and manufacturing of fine chemicals.

Zeolite and nanostructured material technology, solid-state chemistry, solid-state NMR spectroscopy and heterogeneous catalysis are Prof Halimaton's fields of specialization. Her work is focused on the chemistry of nanostructured materials, aerogel, functionalized zeolites and mesoporous materials. Prof Halimaton's contribution to the field of science is in discovering a cost-effective way to turn discarded rice husks into pure amorphous silica *via* controlled pyrolisis technology; from which high value-added silica-based nanostructured materials, specifically Maerogel (Malaysian aerogel), a variety of zeolite absorbents, catalysts and mesoporous materials are developed. Several novel zeolite catalysts were designed and synthesized to provide solutions to current environmental problems; which include conversion of palm oil empty fruit bunches and biomass to biofuel, alcohol to petroleum and carbon dioxide adsorption. Nanostructured materials are of tremendous importance in the high technology industries and creation of new knowledge intensive firms such as coatings, steel, medicine, optics, electronics and energy. In these industries, nanostructured materials in the forms of polymer nanocomposites, zeolites, mesoporous materials, aerogels, hybrid catalysts, functional electronic structures and devices provide a new set of possibilities for fundamentally improving the performance and applicability.

Prof Halimaton has successfully demonstrated that in-depth understanding in the chemistry of elements and molecules is crucial, which may be further applied to manipulate structures and chemical properties of local natural resources and create novel, commercially viable nano materials with enhanced properties. Through years of research, she has proven that it is possible to create wealth from waste and has successfully applied science through R&D to synthesise novel materials and innovate new products to commercialisation.

She has continuously disseminated her knowledge and findings through lectures, journal publications, academic books, newspapers, mass media reports, technical and conference presentations. She has successfully supervised 40 post-graduates and mentored many scientists and experts.

Prof Halimaton holds numerous professional positions and has chaired several task forces and committees. She is a Fellow of National Science Research Council, National Professor Council, Council Member of Academy of Sciences Malaysia, Malaysia Scientific Association and International Golden Key Society. She is a Steering Committee of EU ICPC Nano Network, an Executive Committee Member of Asia Nano Forum, Brain-Gain Malaysia (BGM-Nanotechnology) and Member of National R&D Think Tank Committee (MOHE). Prof Halimaton was responsible for the development of Ibnu Sina Institute for Fundamental Science Studies UTM, where she was the Director from 2000–2006. She was the Executive Director of Enabling Science and Nanotechnology Research Alliance UTM and a Senate Member of UTM since 1998. She initiated the Excellent Scientist Programme UTM in 1999; from which has emerged hundreds of first-class Malay science graduates.

Her pioneering involvement in driving the Malaysian nanotechnology initiatives since early 2000 led to her secondment to MOSTI in 2011, to head the National Nanotechnology Directorate. Prof Halimaton is an experienced editor and reviewer including *J. of Industrial and Engineering Chemistry Research*, Univ. of Texas Austin, USA, *J. of IEM Malaysia Chapter, Science Letters* (UiTM), *Materials Letters* (Elsevier), *Buletin Kimia* (UTM) and *J. of Mol. Catalysis* (Elsevier). She also has a diploma in translation from Dewan Bahasa dan Pustaka and translated Physical Chemistry, 4th edition by Atkins in 1990.

She won numerous local and international acclaim for her scientific research over the years. Her strength in research led her to be awarded UTM Researcher Award twice and in 2008 the university declared her UTM Imminent Researcher. Following a string of international and national research awards, in 2009, she was declared the coveted Merdeka Award for Health, S&T category by Petronas, Shell and Exxon Mobil.

Other major awards include Petronas Inventors Award (1993), Women Scientists Hall of Fame, National Science Center (1996), UTM Publication Award (2002), Seoul International Invention Fair (2002) and National Intellectual Property Award (2006). Maerogel received global recognition by being selected as product of the year; exhibited at the Science News! from Asia — Power of Science Exhibition, Miraikan, Japan in 2007. She received a Gold Medal Award from Malaysian Women Organization UMNO (2009), IFIA Cup for Woman Inventor (2008) from the International Federation of Inventors Association and Great Women of Our Time Award (GWOT 2008) from *Malaysian Women Weekly*. She also received the World Invention Glass Oberlisk Award at the British Invention Show (BIS2007) for the Biphased Nanostructured Catalyst. Maerogel was featured in a program entitled *Spirit of Innovation* — CNN (2008) and received global media coverage by Associated Press. The most recent accolade is the Green Excellence Award 2010 for Building Insulation Product Innovation from Frost and Sullivan Malaysia.

She has been an advocate of science and mathematics education and is a member of the National Committee for 60:40 Science to Arts education at the Ministry of Education Malaysia (2012). She is a fellow of Academy Sciences Malaysia, Institut Kimia Malaysia and Malaysian Scientific Association, member of the National Science Research Council, NanoMalaysia Board, Malaysia Professor Council and President of Malaysia Nanotechnology Association. She is currently the Vice Chancellor of University Malaysia of Computer Science and Engineering in Cyberjaya; a newly established boutique university, designed to bridge the gap in the demand and supply of computer scientists and integrate science into computing technology. Over the years she has contributed to the advancement of women in science and engineering thorough the National Council of Women's Organisations, Loreal, Malaysian Science Toray Foundation and *Wanita Teknologi (WANGI)*.

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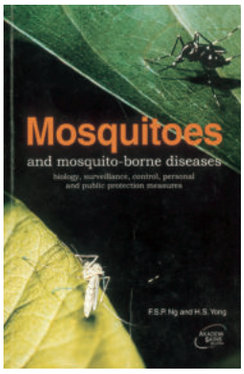

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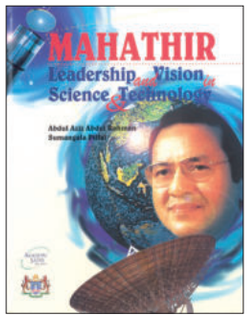

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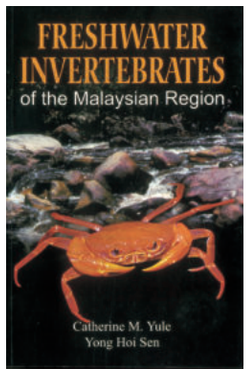

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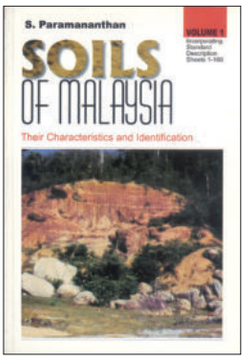

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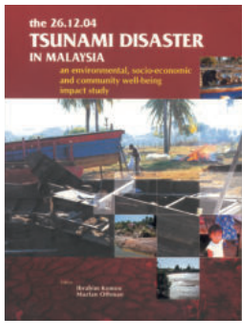

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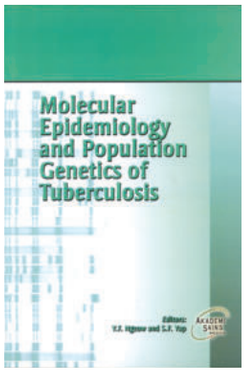

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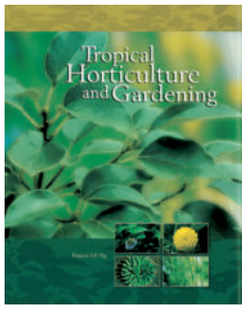

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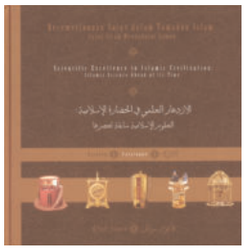

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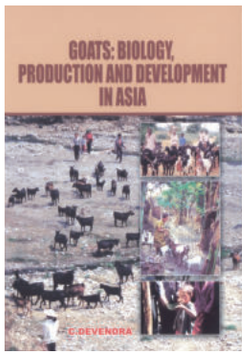

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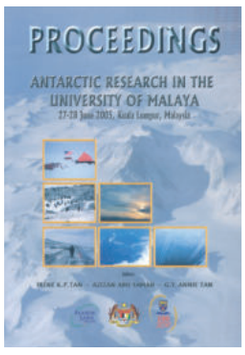

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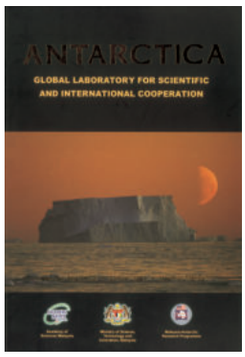

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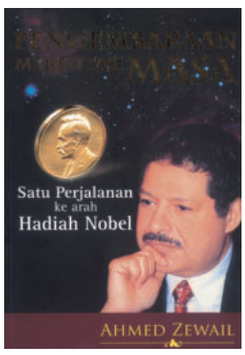

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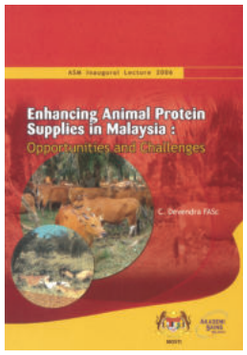

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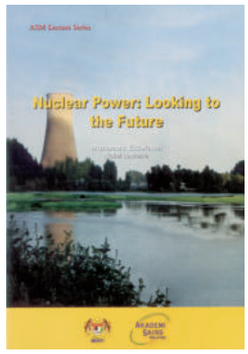

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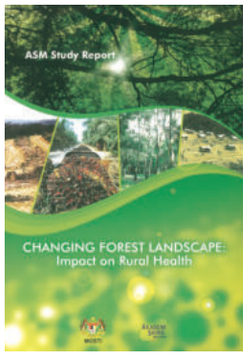

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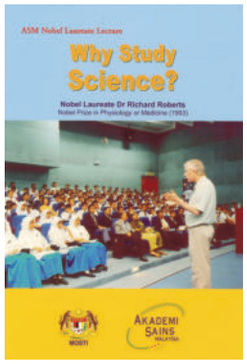

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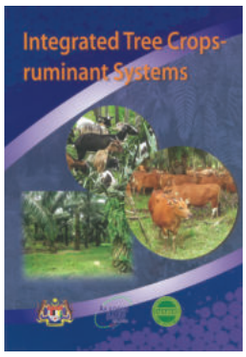

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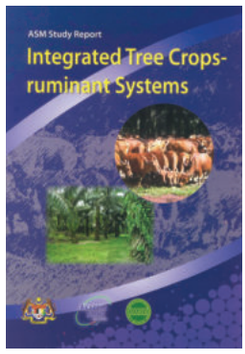

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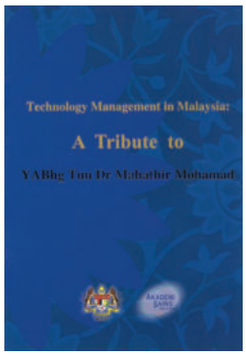

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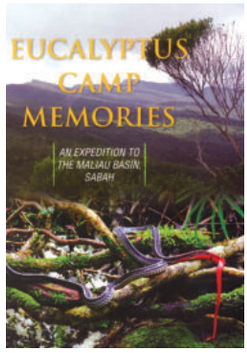

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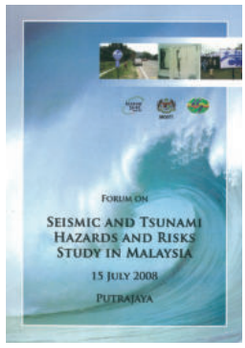

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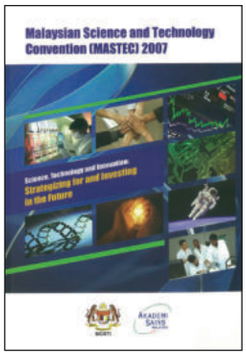

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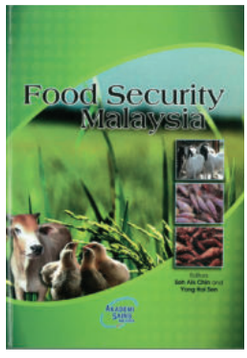

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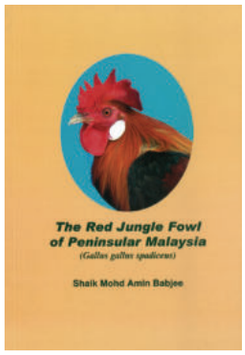

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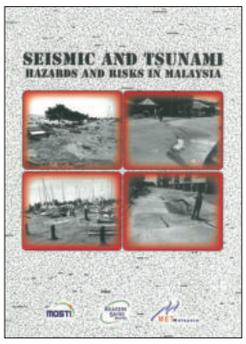

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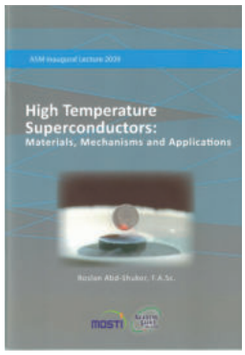

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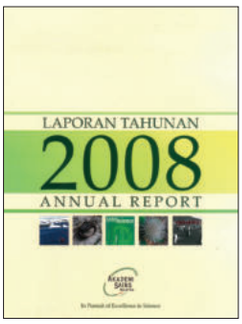

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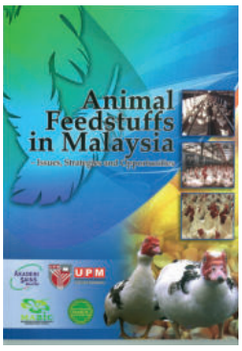

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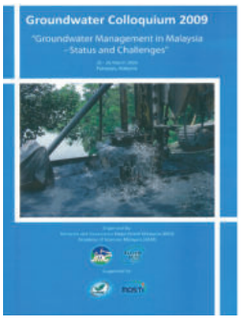

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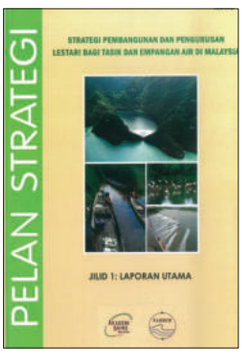

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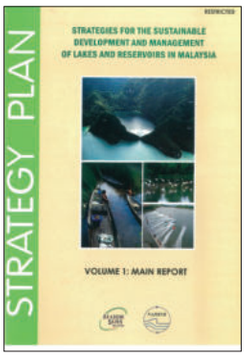

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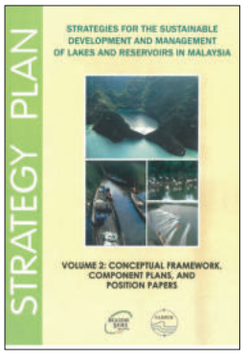

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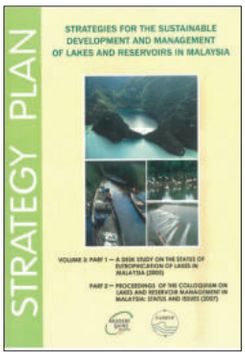

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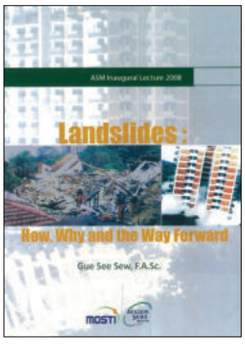

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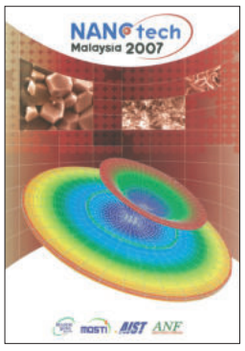

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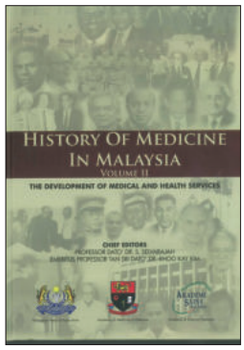

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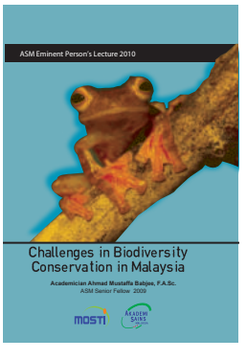

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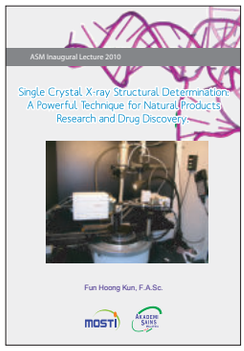

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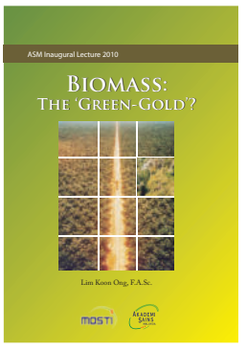

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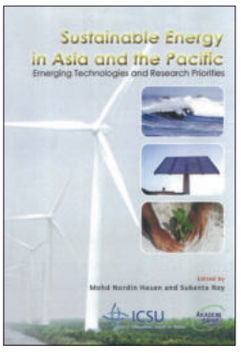

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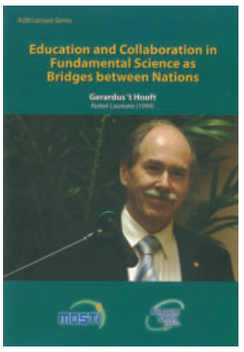

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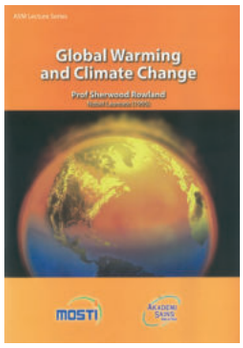

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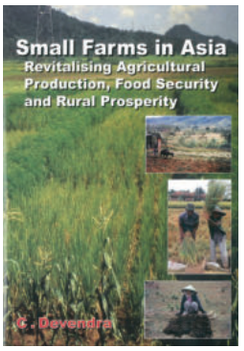

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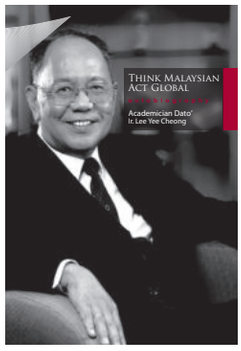

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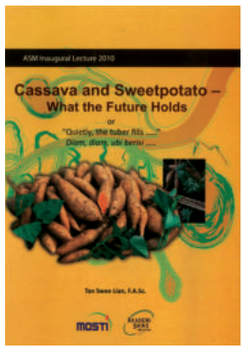

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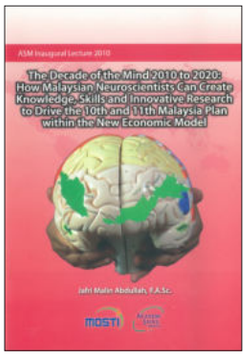

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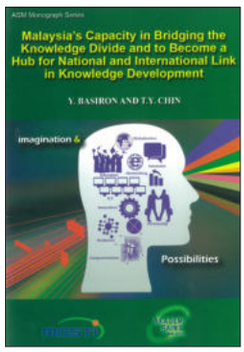

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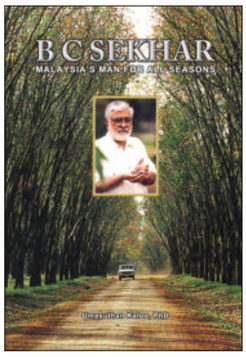

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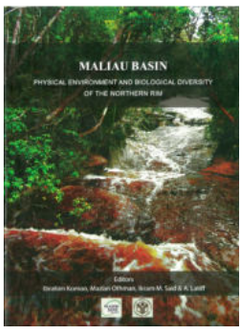

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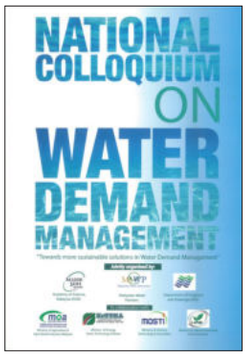

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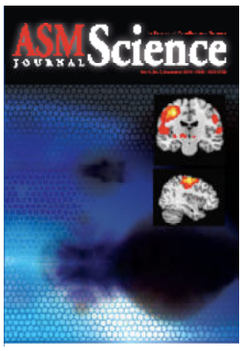

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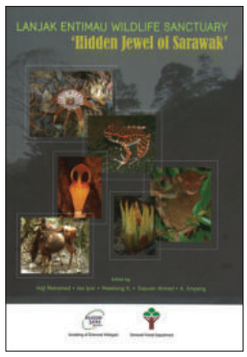

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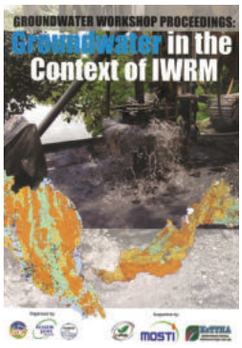

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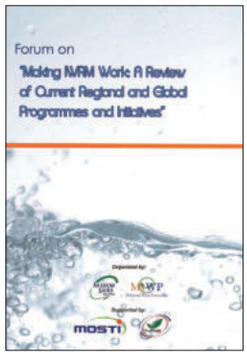

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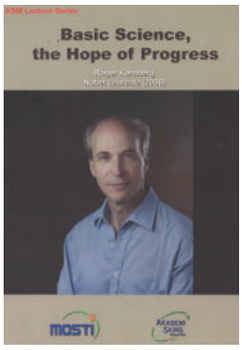

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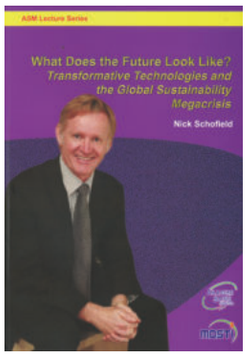

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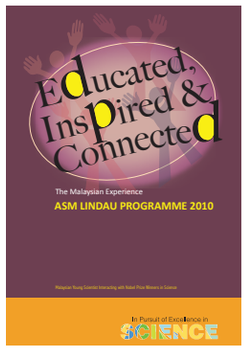

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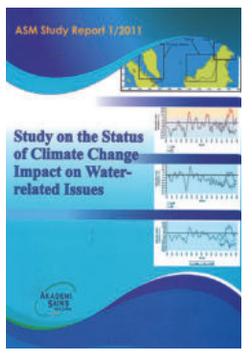

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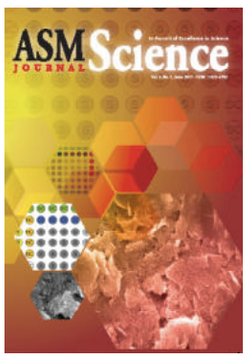

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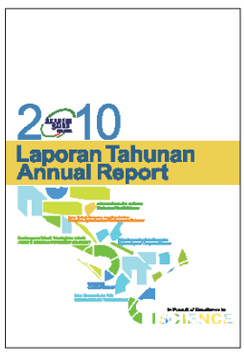

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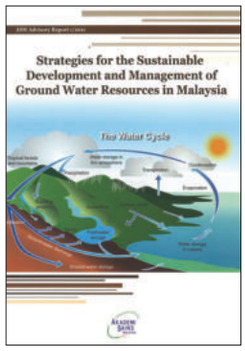

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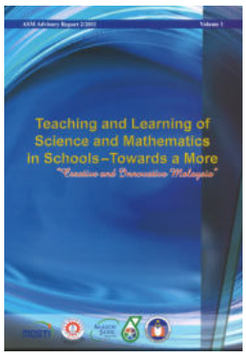

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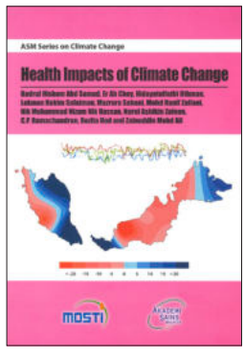

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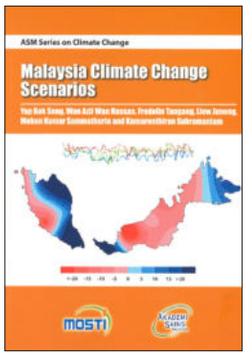

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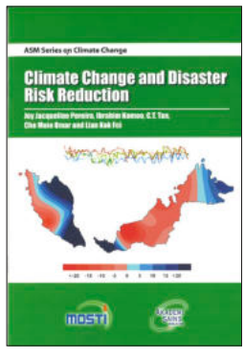

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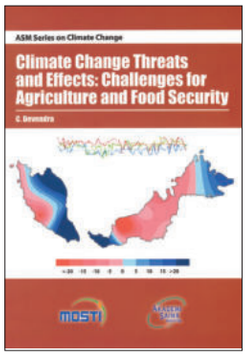

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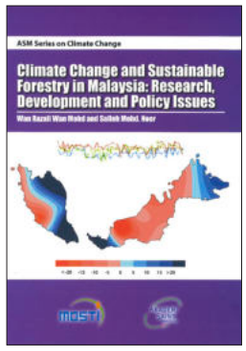

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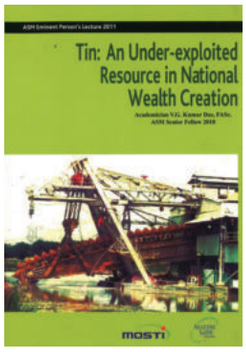

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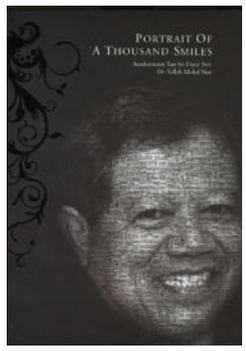

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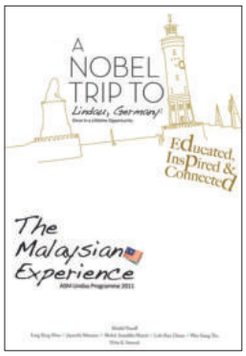

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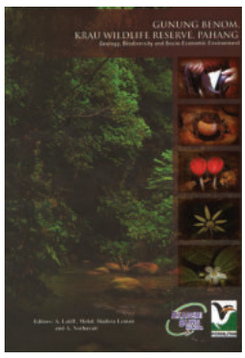

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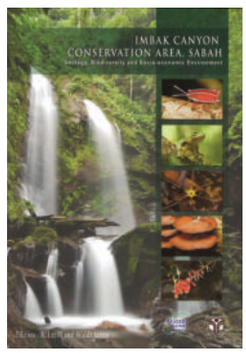

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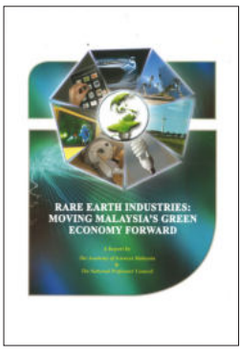

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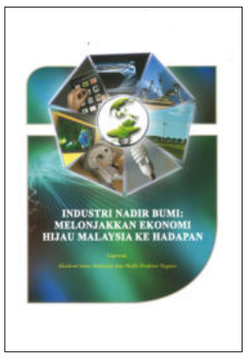

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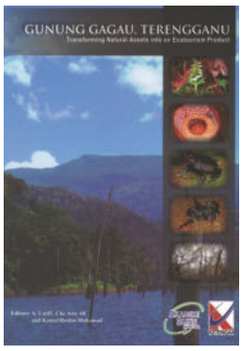

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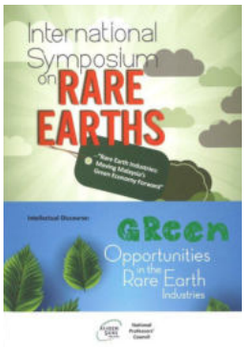

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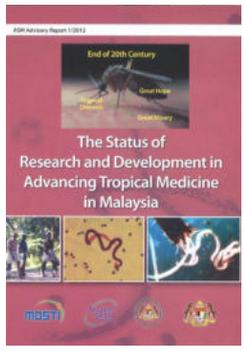

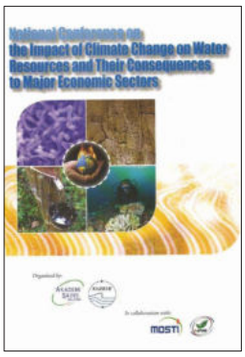

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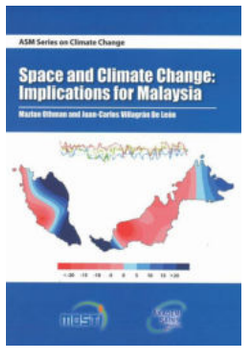

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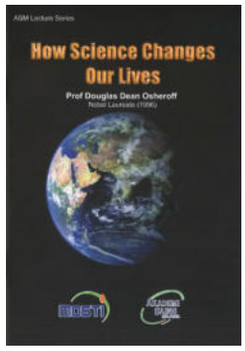

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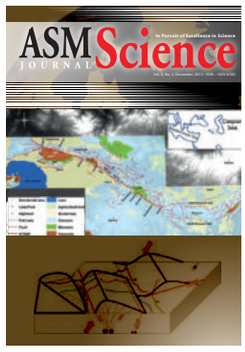

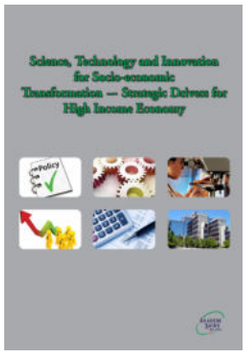

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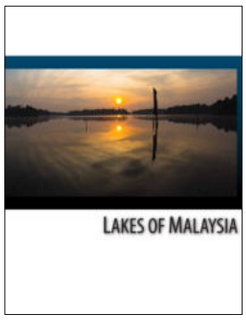

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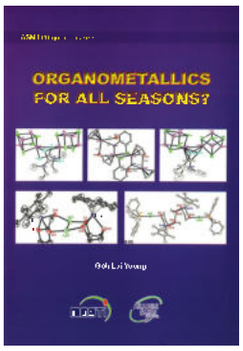

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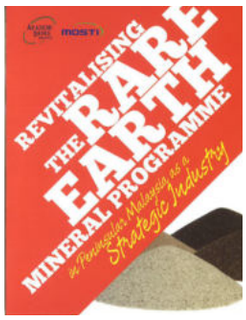

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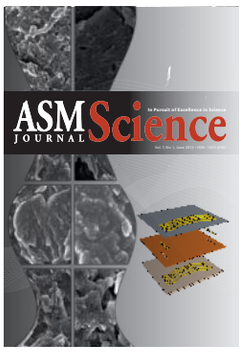

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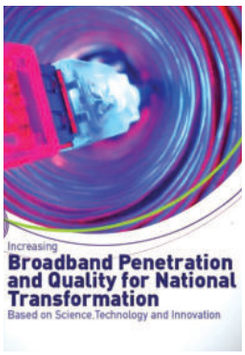

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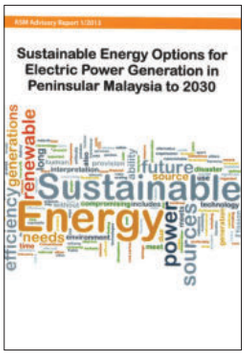

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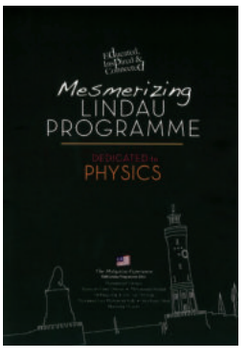

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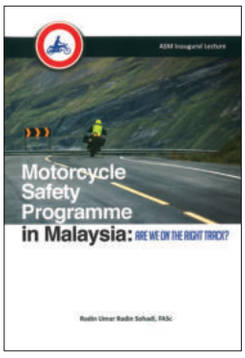

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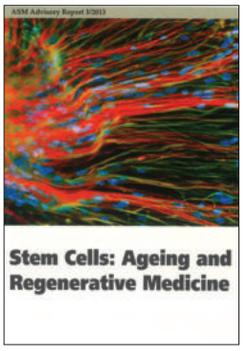

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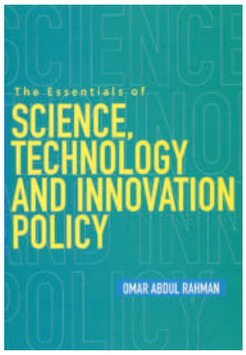

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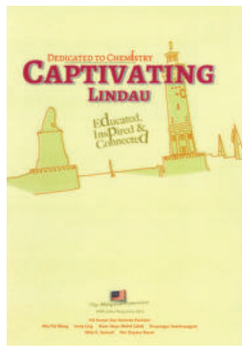

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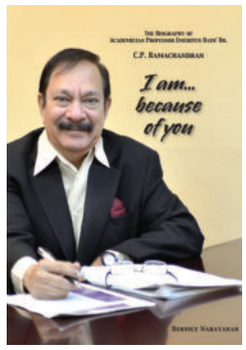

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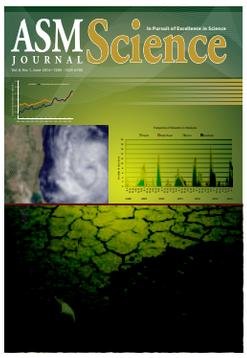

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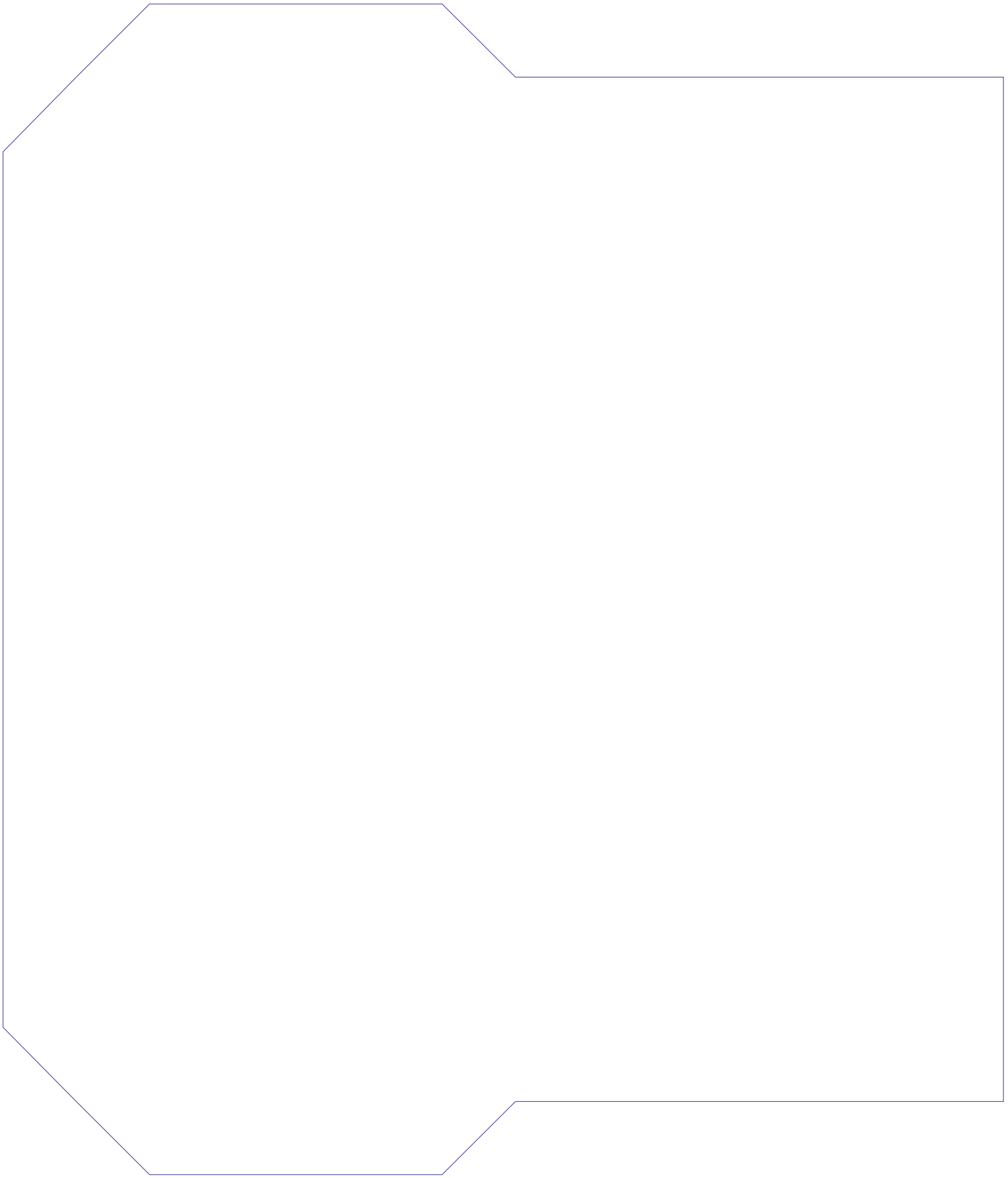

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