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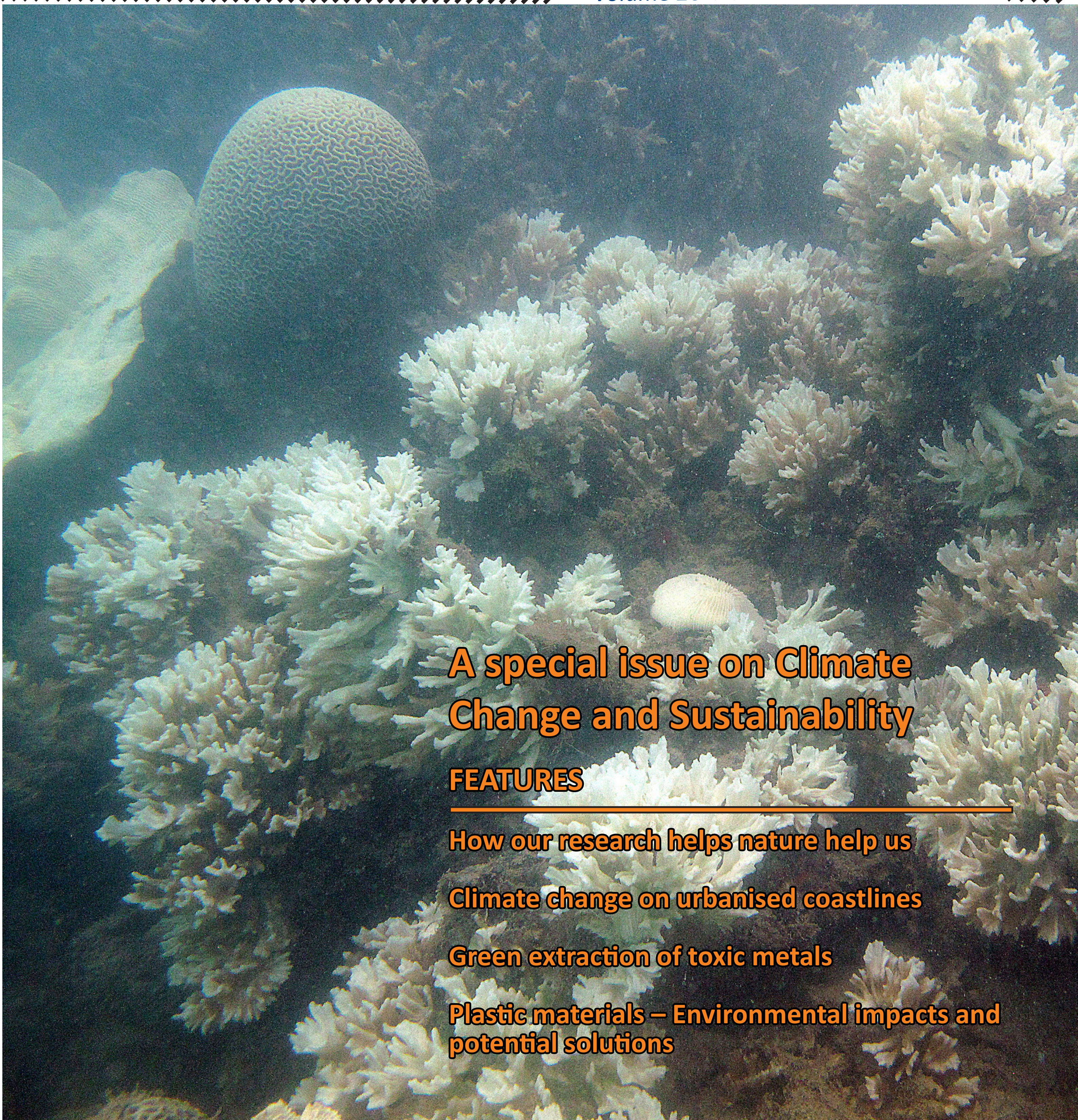

A special issue on Climate Change and Sustainability

FEATURES

Table of Contents

RESEARCH FEATURES

FACILITIES

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On the cover: Coral bleaching on reefs in Singapore due to ocean warming.

How our research helps nature help us

Nature-based climate solutions as cost-effective mitigation strategy against climate change

Introduction

As scientists paint an increasingly dire picture of the climate crisis, a burgeoning body of research points to the potential of nature-based climate solutions (NCS) to substantially reduce greenhouse gas emissions that are heating our planet while putting the brakes on global biodiversity loss. Even as nations race to decarbonise their economies, there is growing consensus that these solutions will be needed to offset emissions that countries and corporations struggle to eliminate, making them critical to forging a path to net zero. Yet as their implementation continues to face a myriad of regulatory and technical hurdles, the question of how to scale them at the speed required to avert the worst impacts of climate change remains shrouded in uncertainty. Our Centre for Nature-based Climate Solutions is developing the cutting-edge science and technologies required to firmly place these solutions on political agendas. It is our interdisciplinary approach and ambition to engage political and business leaders to translate science into action that makes our work unique.

Nature-based climate solutions

We know what these solutions look like. As diverse as they are effective, options include the protection, restoration and improved management of natural and human-modified ecosystems such as forests, wetlands or croplands to boost natural carbon sequestration and climate resilience. On the ground, projects range from rewetting peat swamps and replanting mangroves to safeguarding vulnerable rainforests and reducing reliance on nitrogen fertilisers for food production. As more organisations purchase carbon credits, we also know how to fund these solutions. In 2019, the rising demand for high-quality credits resulted in a 30 per cent year-on-year increase in the average price of nature-based carbon offsets. If this upward trend carries on, more conservation initiatives that traditionally would have wilted under pressure from intensive agriculture, forestry and other lucrative land uses may become financially viable, simply because selling carbon credits for the carbon that a forest sucks from the air may generate more revenue than cutting the trees down to make room for industry or plantations.

However, NCS continue to face multiple stumbling blocks. Gaps in knowledge essential for supporting and informing investment decisions have persisted, including uncertainties around where the richest carbon stocks are located, how much carbon they sequester over time, and how they can best be restored, monitored and governed. Very little is still known in particular about coastal ecosystems such as seagrasses and seaweed, as well as the interconnectedness and interdependence between various natural ecosystems and their carbon sequestration properties.

These research gaps are a major contributor to the opaque nature of carbon products in the market today, deterring prospective investors and buyers of credits alike, thus making it difficult to mobilise capital and get projects off the ground. The fact that less than 3% of global climate finance presently flows towards NCS is a case in point. Easing investor concerns over the integrity of carbon projects will require new methodologies that can reliably derive context-specific and accurate estimates of carbon yield. Implementing a nature-based carbon project without these data is akin to growing an agricultural crop without the ability to measure and predict the volume of production. Exacerbating this predicament is that carbon, of course, cannot be harvested like other commodities. As a result, the credibility of carbon credits hinges entirely on the scientific models behind the accounting process.

Centre for Nature-based Climate Solutions

Since the inception of the National University of Singapore's Centre for Nature-based Climate Solutions, my team and I have worked ardently to identify and address these knowledge gaps. Over the last 18 months, we have focused our research efforts on a few priority research questions related to clarifying the potential and limitations of forest protection and reforestation as nature-based solutions. Notably, our research has found that financially viable carbon projects in the world's tropical forests could generate return-on-investment amounting to an astonishing US$46 billion per year in net present value, with the majority of profitable tropical forest conservation sites located in the Asia-Pacific region. Another spatial study we conducted showed that the protection of approximately 20 per cent of the world's mangrove forests is fundable through carbon financing, underscoring the vast potential of these extraordinary wetlands to meet national-level climate mitigation goals. Reflecting such findings, a report our Centre penned in collaboration with Conservation International made the business case for NCS in Southeast Asia, demonstrating that nature-based carbon projects are cost-competitive with other mitigation options but stand out as particularly promising when co-benefits are considered. We have also modelled reforestable areas in urban spaces to show that 1,189 cities around the world could offset more than 25% of their carbon emissions through tree planting. Often perceived as negligible, opportunities for natural climate mitigation in cities clearly deserve a place on political agendas.

Our goal has been to produce data-driven, policy-relevant science that addresses the unknowns in this important field and delivers pragmatic solutions and innovations. To maximise the impact of our research, we collaborate with stakeholders across the public, private and people sectors in Singapore and beyond, communicating scientific insights in an accessible and salient manner to build capacity and inform decision-making processes.

Yet much remains to be done to unleash nature's full potential. While investing in natural ecosystems can yield handsome profits, our research shows that about 80% of global tropical forest carbon stocks identified as theoretically fundable through carbon finance are economically unviable under current market conditions for failing to break even over the project lifetime. This underlines the crucial need to raise carbon prices, overcome regulatory hurdles, and introduce complementary conservation interventions that take valuable ecosystem services other than carbon sequestration into account. In another paper, we mapped Southeast Asia's reforestation potential by combining analyses of the biophysical suitability for tree planting and the financial, social and operational challenges to forest restoration, finding that only a fraction of the region's natural climate mitigation potential may be achievable unless constraints can be sufficiently addressed.

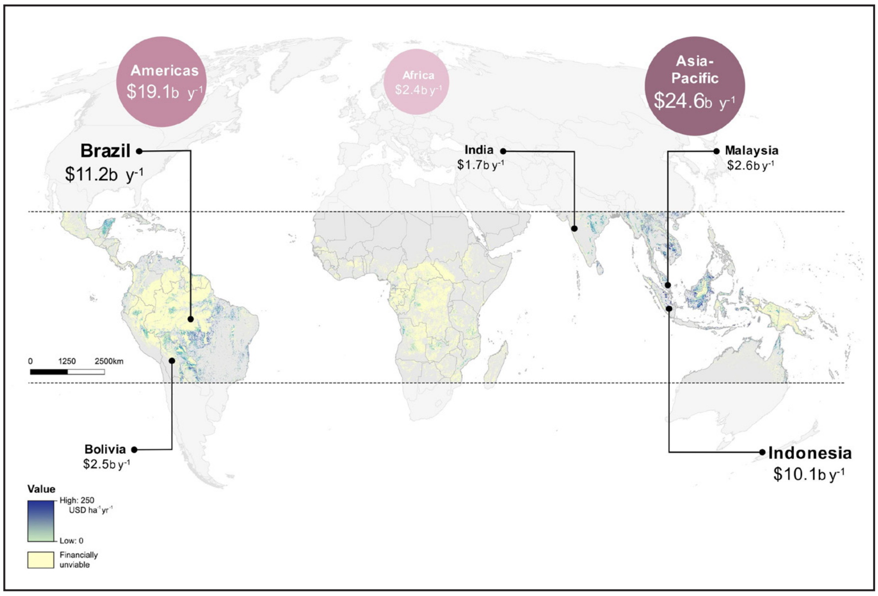

Figure 1: Global forest carbon return-on-investment from financially viable sites over the next 30 years, as calculated in our paper titled Carbon prospecting in tropical forests for climate change mitigation. The majority of financially viable sites are located in the Asia-Pacific region, followed by the Americas and Africa. Brazil, Indonesia, Malaysia, Bolivia and India hold the largest potential for forest carbon projects.

Beyond investment in research and technology, this will require coordination across the Association of Southeast Asian Nations, according to another report our researchers recently produced together with the University of Nottingham to inform the 26th United Nations Climate Change Conference held in Glasgow. Even the many other benefits that NCS have been shown to deliver, such as biodiversity conservation, clean air and water, coastal resilience, flood prevention, food security, and livelihood opportunities, are at risk of being overlooked unless they can be dependably quantified and the science compellingly communicated. Nowhere is this more important than in the Asia-Pacific region, where nature and biodiversity loss potentially threaten 63 per cent of gross domestic product, or US$19.5 trillion, due to the region's economies' high dependence on natural resources [1].

In the years ahead, our Centre strives to surmount these and other obstacles. Research has shown that NCS can deliver over a third of cost-effective climate mitigation needed through 2030 to keep the global temperature rise below 2°C [2]. We will do our utmost to ensure they do.

For more details, please visit:
https://www.dbs.nus.edu.sg/staffs/koh-lian-pin/

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Climate change on urbanised coastlines

Impacts of ocean warming and sea-level rise on coastal ecosystems must be mitigated alongside local effects arising from urbanisation

Introduction

Coastal and marine ecosystems in Singapore have been impacted by intense coastal development and urbanisation over the last half a century, as the island nation expands in area seaward to accommodate activities in the shipping, transportation and petrochemical industries. Consequently, Singapore has lost significant areas of its natural ecosystems, including coral reefs, mangrove forests and seagrass meadows. The natural habitats that remain have maintained relatively high diversity, but are now under threat from climate change impacts. At the Reef Ecology Lab, we work with our collaborators to understand these impacts, project the future of these habitats, and devise solutions and management strategies to curb further losses.

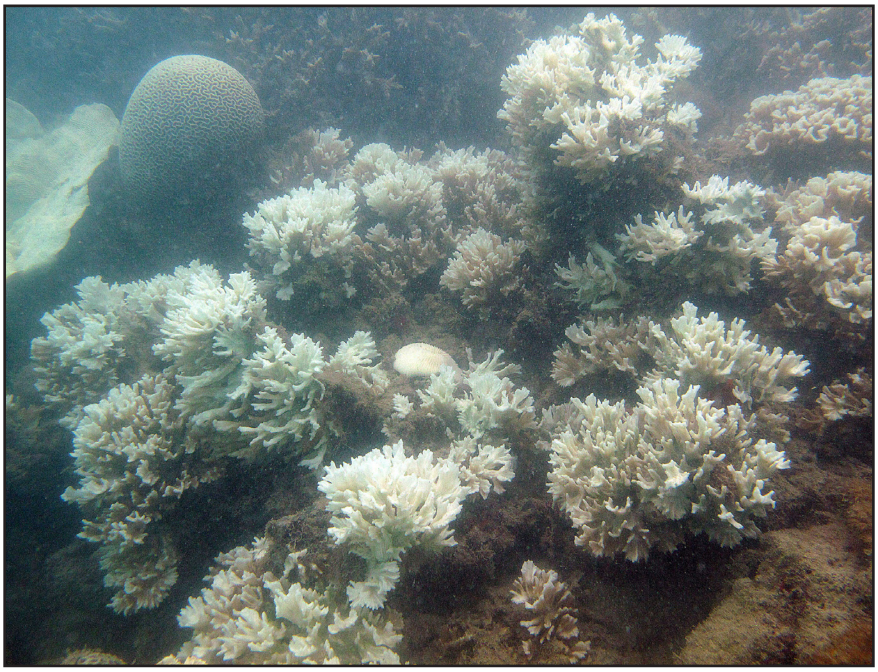

Figure 1: Coral bleaching on reefs in Singapore due to ocean warming.

Coral bleaching on urbanised reefs

Increasing sea temperatures stemming from climate change have pushed many marine organisms and ecosystems beyond their physiological limits. The most extreme episodes of warming occurred during marine heatwaves that have increased in severity and frequency over the last two decades. There is perhaps no other more visual manifestation of heat stress than coral bleaching, which occurs when reef-building corals are stripped of their symbiotic algae and turn ghostly white (see Figure 1). The symbiotic algae supply most of corals' energy requirements, so they need to be recruited back for coral hosts to continue living and providing ecosystem functions. This recovery can take months, and many corals perish during these bleaching events. For coral reefs that are also impacted by urbanisation in Singapore, it is critical to predict their bleaching responses to manage further losses of reef biodiversity and habitats.

During the last global-scale coral bleaching event in 2016, we investigated these responses at various reef sites in Singapore [1]. Our results show that the prevalence of bleaching varied widely and was best explained by the specific coral species present at each site. Those with more species tolerant against heat stress were minimally impacted, while others with more susceptible species registered significant declines in reef health that persisted through 2017.

Bleaching resilience—the capacity to recover and regain pre-bleaching pigmentation levels—was also variable among species and reef sites. In fact, it was only in 2021 that all the reefs recovered their pre-bleaching conditions. The high turbidity at very sedimented reef sites appears to have some positive effects on the recovery rate, indicating a complex interplay between local conditions and species composition that drives bleaching outcomes on urbanised reefs. This study underscores the importance of a deeper understanding of corals' biological traits for predicting the future of reefs and to formulate effective management strategies.

Sea-level rise on turbid reefs

Apart from ocean warming, marine environments are also faced with rising sea levels, which can significantly alter environmental parameters such as light, temperature and sedimentation regimes on coral reefs. These changes can impact corals in the light-limited environments of turbid reefs, including the urbanised reef communities of Singapore that have been subject to extensive impacts from coastal reclamation and development since the 1960s. As part of the project "Adaptation and resilience of coral reefs to environmental change in Singapore" supported by National Research Foundation Singapore's Marine Science Research and Development

Programme, we examined corals' depth ranges in relation to how they might cope with the impacts of persistent local stressors and accelerating sea-level rise.

Based on observations of nearly 3,000 colonies recorded from the entire depth range of reef corals in Singapore, we found clear environmental covariations with depth [2]. Light exhibits the most predictable decline with depth, affecting live coral cover and species diversity significantly. Indeed, light attenuation deeper in the water column limits the depth distribution of corals because growth rates of corals reliant on symbiotic algae are reduced. Our study offers direct empirical evidence for these light- and depth-associated effects at the reef level. Interestingly, shallow coral species tend to be specialised to live primarily in the shallowest parts of the reef, while deeper species tend to have wider depth ranges. Therefore, corals in Singapore are likely to be resilient against light limitation as the sea level rises because the deeper species are able to live in shallower areas and persist through the reduction in light levels. The detailed distributional data on corals also inform conservation efforts in the selection of sites and depths for coral transplantation and restoration.

Maximising ecosystem resilience

Scaling up research on marine species and communities to ecosystems is important for climate change adaptation. Indeed, coastal habitats can play important roles in the overall sustainability and resilience of urban centres by providing coastal protection. Conserving coastal ecosystems and

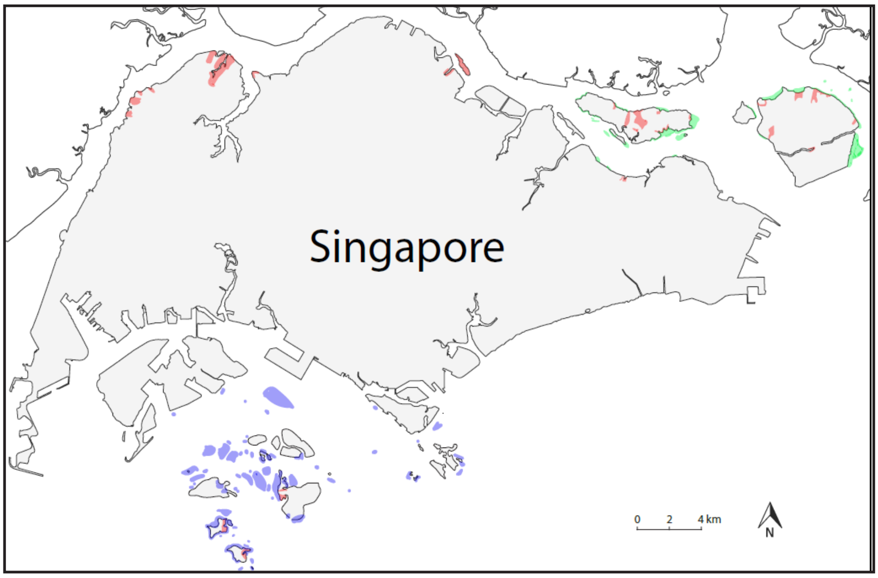

Figure 2: Distribution of marine habitats in Singapore: coral reefs (purple), mangrove forests (red), and sand/mudflats (green).

maximising their resilience will ensure that urban coastal communities can continue to benefit from ecosystem services and improve their adaptive capacity. We have modelled the resilience of Singapore's coastal habitats to sea-level rise and performed conservation planning by integrating various aspects of biodiversity and resilience, supported by an Australia-Singapore Joint Research Grant from the National Research Foundation Singapore.

Our models—based on the extent and elevations of coastal ecosystems (see Figure 2)—project the areas of each habitat under sea-level rise conditions through the end of this century [3]. The results show variability among habitats and times. While there are projected gains in the overall extents of mangrove forests and seagrass meadows due to potential habitat conversion by 2025 and 2050, respectively, the end of the century could see net declines if wetlands are prevented from migrating to higher ground. Existing habitats will almost certainly experience losses. Urbanised areas that are lined with seawalls or infrastructure can impede the ability of existing wetlands to migrate landward, which is a key mechanism for coastal habitats to cope with rising sea levels.

Finally, we performed systematic conservation planning to identify coastal areas including the projected habitats that are potentially resilient to climate change by integrating socio-economic, environmental and ecological factors that could influence ecosystems' capacity to respond to change. Crucially, the relatively slow rates of sea-level rise and persistence of coastal wetlands during the earlier half of this century present an opportunity to introduce management interventions aimed at enhancing ecosystem resilience.

For more details, please visit:
https://coralreef.nus.edu.sg/

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Green extraction of toxic metals

Saving landfill space at Semakau island while producing clean sludge for agriculture use and also for construction materials

Introduction

In 2018, around 2,200 tonnes of waste were sent daily to Semakau Landfill, Singapore's only landfill. This waste comprises incineration ash and non-incinerable waste. At this rate, the landfill is expected to run out of space by 2035. The National Environmental Agency (NEA) recognises this issue and has allocated S$45 million for the "Closing the Waste Loop" research and development (R&D) initiative in support of Singapore's vision of a zero waste nation. This initiative solicits R&D proposals to discover ways to avoid or reduce the disposal of non-incinerable waste at Semakau Landfill and to recover value from it.

One environmental issue associated with landfills is potential contamination from heavy metals. Toxic heavy metal contamination of solid sludge and the surrounding land may lead to subsequent leaching to groundwater. This is a growing global concern at many waste sites. Toxic metals commonly found in waste streams include lead, cadmium, mercury, chromium and arsenic. Other less toxic metals such as nickel, copper, zinc, barium, manganese, cobalt, tungsten and molybdenum may also cause contamination. Industrial, mining or commercial sites where toxic production residues are improperly stored or buried may also contribute to this issue. In other instances, contamination may be the result of leakage or mishandling during transportation of these hazardous materials. Besides causing groundwater pollution, solid sludge contamination usually results in restricted utilisation of these sites and, in some cases, a complete prohibition of agriculture cultivation or other potential uses of the affected area.

Zero waste green extraction of heavy metals

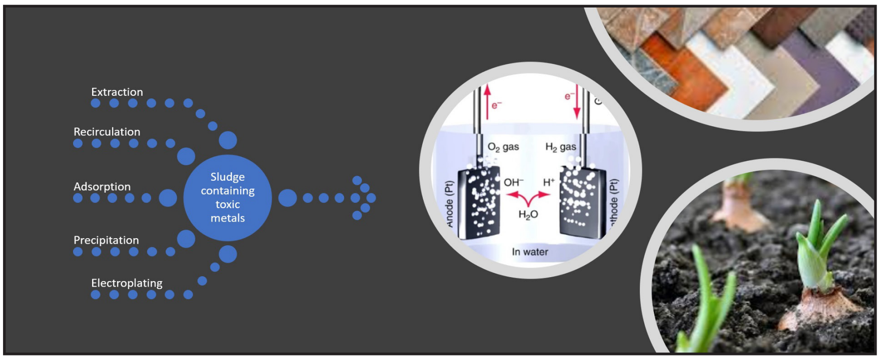

Figure 1: Proposed treatment process to cleanup sludge contaminated by toxic metals for recycle and reuse in construction materials, energy production and agriculture.

Chemical remediation (cleanup) is one of the three main categories of remediation techniques for managing solid waste contaminated with heavy metals. The other two categories are physical remediation and biological remediation.

Chemical remediation mainly includes immobilisation/stabilisation, smelting, and chemical washing techniques. The immobilisation/stabilisation technique adsorb, chelate, precipitate or encapsulate heavy metals with the use of chemical additives to prevent them from leaching back into the environment. The cost of using the immobilisation/stabilisation technique ranges from low to medium, but this comes with the potential leaching risk of heavy metals due to the remobilisation of the metals. The smelting technique uses the sludge contaminated with heavy metals as one of the components in the production of cement under high temperatures. This effectively traps the heavy metals within the cement. However, this sacrifices the safety of final cement products and carries the potential leaching risk of the heavy metals. The chemical washing technique applies chelating agents or acid to release heavy metal ions on sludge particles. This is followed by a solid/liquid separation and wastewater treatment to remove the hazardous contaminants. Chemical washing is usually costly due to the large consumption of chemicals, and it carries a risk of secondary contamination if the wastewater generated is not properly handled and treated.

Our approach shows preliminary results

Our team (which includes Associate Professor Jason Boon Siang YEO, Senior Research Fellow, Dr LIN Xuanhao and Master's student Ms LIU Qiuran) has started working on a three-year research project on "Cost-Effective Removal and Recovery of Heavy Metals from Non-Incinerable Wastes for Recycling and Reuse with Near-Zero Waste Discharge". This project is supported by the NEA in collaboration with NSL Chemical Ltd and Origgin Venture (Singapore) Pte Ltd, and aims to develop a cost-effective method to remove and recover heavy metals from solid wastes for recycling and reuse.

In this project, we plan to reduce the amount of waste earmarked for the landfill, and at the same time derive valuable products from it. We have developed a laboratory scale prototype comprising of circulating pumps and four treatment tanks (see Figure 1 and Figure 2). Sludge containing heavy metals are placed in the first treatment tank and extraction solutions are recirculated to extract the heavy metals. The extracted heavy metals are then adsorbed by the enriching adsorbent in the next treatment tank. After the adsorbents are saturated with metal ions, the heavy metals are stripped away by suitable releasing solutions in the third treatment tank. The recovered heavy metals are then selectively electroplated onto electrodes in the final treatment tank. The electrodes containing recovered heavy metals which are produced from this process can be used for renewable energy generation (e.g. hydrogen production). In this setup, all the solutions are recirculated, and the adsorbents are reused.

Recent chemical remediation developments include the use of biochar (a type of carbon rich material) in sewage sludge to prevent the leakage of nickel and zinc contaminants and the use of carbon dots/magnesium hydroxide sheet composite for adsorption of toxic cadmium ions. In comparison, the proposed approach takes a more overall view. The key advantage being that the process operates sustainably within a closed loop and no wastewater is discharged.

Potential applications

Major industries producing non-incinerable wastes include the semi-conductor, oil refining, toxic industrial waste treatment, electroplating, and batteries recycling sectors. Incinerated sewage sludge ash mainly comes from water reclamation plants. In Singapore, most of these wastes are sent to Semakau Landfill and the quantity of incinerated sewage sludge ash sent

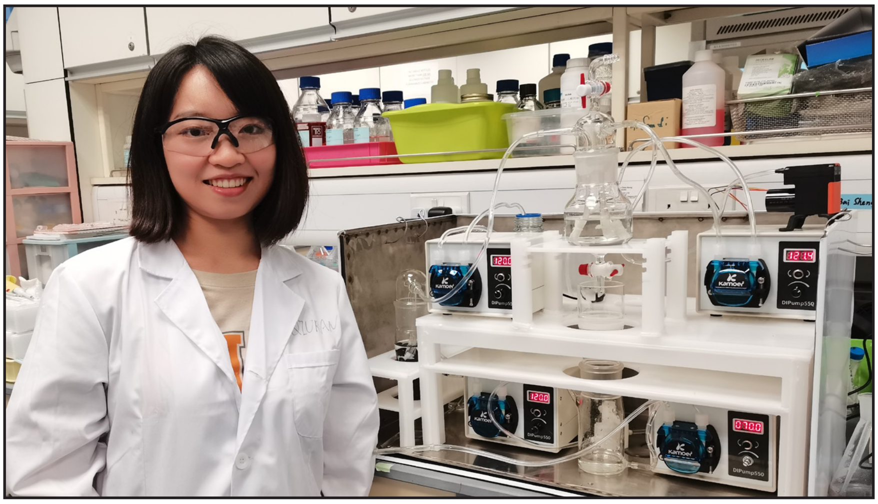

Figure 2: The prototype of the heavy metals recovery system designed and fabricated by Dr Lin Xuan Hao (Senior Research Fellow) and Miss LIU Qiuran (Master's student - Shown in the picture).

to Semakau Landfill can amount to 30,000 tons per year. This translates to roughly 82 tons a day.

Through this project, the method developed to remove and recover heavy metals from solid wastes for recycling and reuse can potentially reduce the amount of waste sent to Semakau Landfill and extend its useful life beyond 2035.

In addition, the proposed process will derive valuable products. The cleaned sludge can now be used to produce construction materials (e.g. ceramic tiles) and recycled heavy metals can be converted to electrodes needed for renewable energy generation. Apart from the construction industry, the treated solid sludge/ash has potential applications in agriculture and horticulture. As it no longer contains heavy metals, it is safe for use as soil amendments to improve certain soil properties such as water retention, permeability and drainage.

When scaled up, this process can potentially provide an alternative for sludge treatment, which will be cost-effective (reduced waste treatment cost and landfill cost), labour-saving (automated operation), environmentally friendly (zero-waste discharge) and revenue generating (building materials and electrodes to benefit the waste management industry) [1-3].

Future plans

We are interested in treating both non-incinerable waste and incinerated sewage sludge ash to reduce the amount of waste which will eventually end up in a landfill. Through our research efforts, we hope to better manage landfills and minimise environmental impacts for a more sustainable future.

For more details, please visit: https://www.samlilab.com/

Sam LI is a Professor with the Department of Chemistry, NUS. He received his B.Sc., Ph.D. and D.Sc. degrees from Imperial College London, United Kingdom. His research interests include environmental science and technology, biosensors, metabolomics and nanotechnology. He has authored/ co-authored more than 400 publications in international peer review journals and has over 30 patents applied/ granted. He serves/ has served on editorial advisory boards of several international scientific journals.

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Plastic materials – Environmental impacts and potential solutions

Understanding the impact of polymers and developing more sustainable solutions

Figure 1: Daily uses of plastic articles.

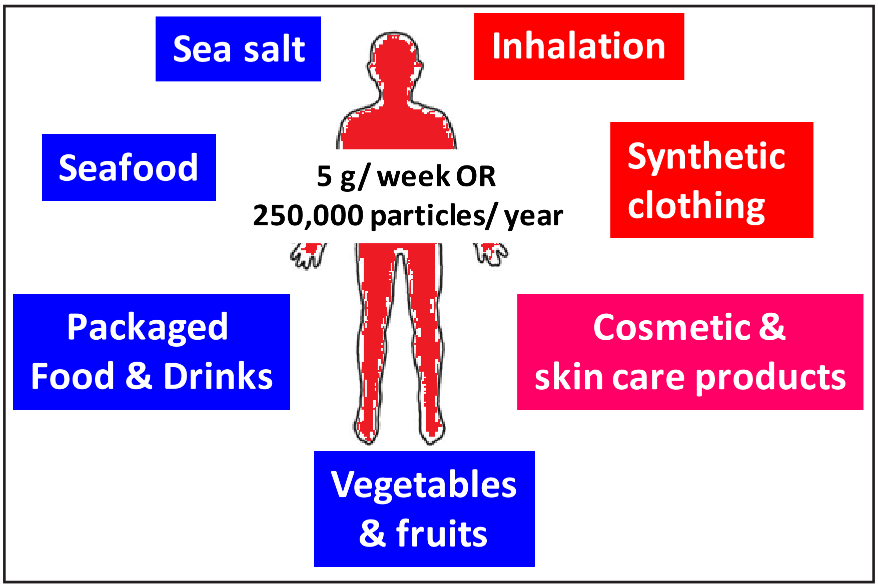

Figure 2: Most common entry of plastic particles into the human body.

Introduction

Polymers are an interesting class of materials used in many aspects of our daily lives. From the toothpaste we use in the morning to the polyester bed sheet for sleeping, we are constantly exposed to many different polymers. In fact, our daily routines and activities are influenced and facilitated by plastic products to a significant extent (see Figure 1). Such widespread use is mainly due to the fascinating properties associated with polymers, which include high mouldability, attractive mechanical properties, high water and chemical resistance, excellent durability, low density and easy access, to name a few.

Nano- and microplastic particles

The high usage of polymers has created significant amounts of plastic waste, which usually ends up in landfills or in waterways. The plastic waste materials degrade under different environmental conditions to release smaller particles and chemicals into the surroundings. The degraded particles, with sizes ranging from 5 mm to 1 µm, are known as microplastics and those with size below 1 µm are called nanoplastic particles. Different research groups have reported that an average human being may unknowingly consume significant amounts (e.g. 5g per week or 250,000 particles per year, etc.) of these plastic particles through various means (see Figure 2). These estimates may increase in the future due to the continued accumulation of plastics in the environment.

My research group at the National University of Singapore is investigating the impact of these nano- and microplastic particles on human health and the environment. Earlier, we reported that metal nanoparticles also cause significant toxicity to living organisms. Analysis of environmental samples such as water, sediments, beach sand, fish, mussels and salt showed they contain a number of plastic particles of varying sizes, shapes and colours. These particles have different chemical compositions and weathering history, which makes understanding their impact on living organisms more complex.

Impact of plastic pollution

Recently, we have shown that luminescent nanoparticles of commonly available polymers prepared in the laboratory are more suitable for use in biological studies

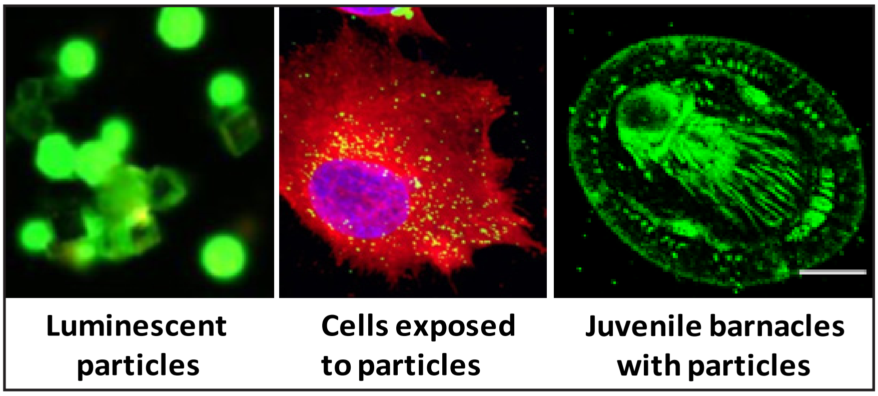

Figure 3: Exposure of luminescent particles to human cells and a juvenile barnacle.

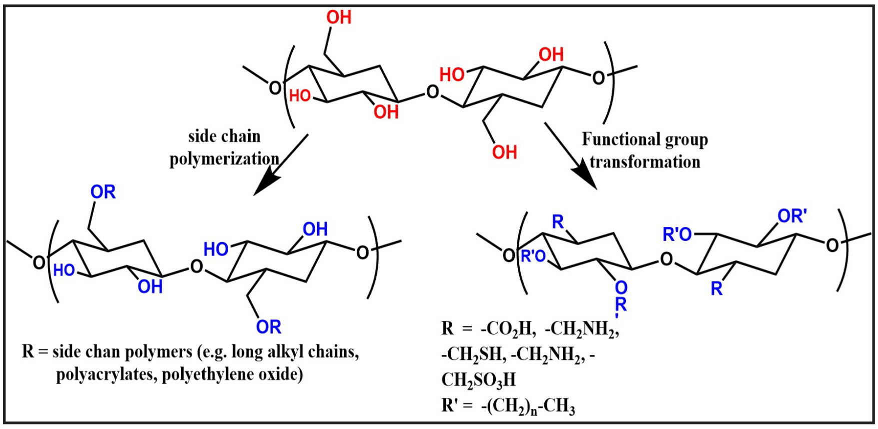

Figure 4: Functionalisation of cellulose.

to understand the impact of plastic pollution. Our synthetic particles have uniform size and spherical shapes, with intense fluorescence emission in an aqueous medium. Such water-dispersible polymer nanoparticles have a size range of 50 nm to 200 nm and can remain stable for a long period of time. Fully characterised polymer nanoparticles are used for investigating the interaction with living organisms (see Figure 3). By working with collaborators in NUS and overseas, we exposed our polymer particles to different living organisms or human cells and investigated the adverse impact on physiological functions. Recent results indicate that the induced toxicity and interactions between polymer particles and the living organism or cellular organelles depend on their chemical composition, size, shape and surface functional groups. While nanoplastic particles were able to enter the organisms or human cells through active uptake, the observed response varied significantly among the different model systems.

Environmentally friendly polymeric architectures

As environmental pollution from synthetic polymer waste is a serious issue, it is important to develop novel environmentally friendly polymeric architectures to replace or reduce the use of synthetic polymers. To this end, we design new types of polymers with full circularity in design, so that after use, these polymers are either recirculated or degraded in an environmentally friendly manner to reduce pollution. This is not an easy task considering that the target polymer must be biodegradable within a short period after use and release only nontoxic materials into the environment. We have identified cellulose as a potential renewable raw material for the development of new polymers. The presence of many hydroxyl groups (–OH) on the cellulose backbone and interchain H-bonds make the cellulose crystalline and non-processable when using conventional polymer processing techniques. This in turn hinders its use in many applications. Cellulose acetate is one the most commonly used natural polymers in industry, but it is not biodegradable due to the high degree of acetylation and its hydrophobic properties. By incorporating functional groups along the cellulose backbone using different routes, it is possible to generate highly processable materials (see Figure 4). We have used such functionalisation techniques to modify the properties of cellulose for water purification and other applications. However, large-scale synthesis and more detailed structure-property investigations are needed to make cellulose an industry- friendly material.

We plan to focus on the synthesis of novel functional molecules and polymers and through our research efforts, we hope to contribute towards making our environment more sustainable in the future.

For more details, please visit: https://chemistry.nus.edu.sg/people/valiyaveettil-suresh/

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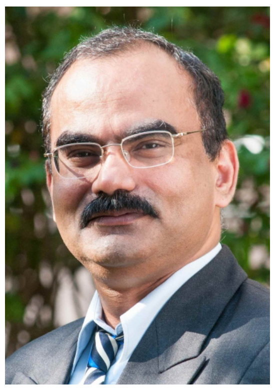

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Centre for Nature-based Climate Solutions (CNCS)

Mangroves in Singapore. These blue carbon ecosystems have gained substantial interest in recent years due to their ability to store more carbon dioxide per unit area than terrestrial forests.

What will it take to firmly place responsible land stewardship on the global political agenda? As scientists sound the alarm over accelerating climate change, the decision to protect, restore or better manage forests, wetlands and other natural ecosystems to ensure they can play a role in mitigating global warming seems obvious. However, it is not that easy.

Despite their outsized benefits, nature-based climate solutions - strategies and actions that support nature's inherent ability to sequester carbon dioxide and build climate resilience - continue to face a range of technical, institutional, regulatory and financial barriers. Given their complexity, these challenges can only be resolved through solid science underpinned by a systems approach that takes political, socio-economic and environmental dimensions into account.

This is what the National University of Singapore's Centre for Nature-based Climate Solutions has set out to do. The Centre is a focal point for world-class research on natural solutions to climate change, thought leadership and education, and brings together a diverse group of experts from different disciplines, departments and faculties to produce technology-driven, policy-relevant science. It also organises compelling outreach campaigns on how to harness natural ecosystems in Singapore and the Asia-Pacific region in ways that are scientifically sound, economically feasible and socially acceptable. These initiatives are intended to help climate mitigation and adaptation while putting the brakes on biodiversity loss.

Through multidisciplinary research and engagements with key stakeholders across the public, private and people sectors, the Centre aims to build the evidence base for informing climate policy, and strengthen capacity to enable society to respond appropriately and decisively to the climate and biodiversity crises while embracing new economic opportunities.

"Nature-based climate solutions will be key to securing a path to carbon neutrality, but the knowledge and methodologies required to scale these solutions fast enough to achieve their full potential is lacking. By establishing and effectively communicating the science needed, our Centre hopes to empower society to work with nature in tackling climate change," said Prof KOH Lian Pin, Director of the Centre for Nature-based Climate Solutions.

For more details, please visit:
https://www.nus.edu.sg/cncs/

Centre for Data Science and Machine Learning (CDSML)

The huge volume of data generated in our daily lives offers great potential for meaningful outcomes and new value, to improve businesses and human well-being.

Rapid advances in social media, internet of things, and cloud computing services have led to a massive explosion of data in our daily lives. While big data provide valuable insights on business opportunities and changing lifestyles, the volume and varied formats of the big data present unprecedented challenges to existing computational sciences and technologies in terms of processing and interpretation.

The Centre for Data Science and Machine Learning (CDSML) was formed in 2021 to respond to the challenges and opportunities of the current data revolution, through a restructure of the Centre for Wavelets, Approximation and Information Processing (CWAIP). CWAIP was founded in 1999 as the first multidisciplinary research centre hosted at the Department of Mathematics which integrated mathematics, engineering and computer science to push the frontiers of mathematical foundation of signal, image and information processing. In tandem with the rapid development of data-related research, over recent years, it also ventured into various areas of imaging science and compressed sensing. With the recent transformation into CDSML, the focus is now on research and education in the current vibrant fields of data science and machine learning.

"Machine learning algorithms empowered by data analytics are changing our work and lives. CDSML leverages core mathematical concepts to understand data-driven machine learning algorithms and make them more capable and effective."

Professor ZHANG Louxin, Director, Centre for Data Science and Machine Learning (CDSML)

CDSML emphasises the synergy of mathematics, statistics and computer science in the domains of data science and machine learning, through research on the foundations of these two domains. For instance, machine learning approaches are used to solve partial differential equations (PDEs) and non-convex optimisation problems and to speed up the convergence of ensemble Kalman inversion for solving non-linear inverse problems. Core mathematical concepts in approximation theory and dynamical systems have been used to demystify deep neural networks. Information theory is used to understand how big data benefit diverse inference and learning problems. Orthogonal polynomial based techniques are proposed for sampling minibatches in stochastic gradient descent. Another research focus area is on the design of algorithms for Bayesian optimisation and other techniques used for training deep learning methods.

At CDSML, state-of-the-art machine learning techniques such as deep learning are used to solve real-world data analytics problems. Deep neural networks are used to reconstruct low-dose computed tomography images, analyse brain images and deblur blind motions on dynamic scenes. Matrix-factorisation methods and other approaches are developed for drug response prediction and personalised drug therapeutics. We also developed models and methods for forecasting demand and supply in the energy market.

CDSML also actively supports the educational goals of the University by training research graduate students and offering the Master programme in Data Science and Machine Learning (DSML). It also offers data analytics consulting services to businesses and government agencies.

For more details, please visit:
https://www.math.nus.edu.sg/cdsml/

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