Science Last Fortnight

Uranium from Seawater

Searching for adsorbents

Uranium, a heavy metal used as nuclear fuel, is widely available in the earth's crust and in seawater. Seawater has uranium at a concentration of 3 micrograms per litre. Oceans have five billion tonnes of uranium waiting to be extracted.

Researchers have tried different methods for large-scale uranium extraction from oceans. Composite adsorbents that use poly(amidoxime) composites are most commonly used as they are efficient, low cost and easy to handle. But there are hurdles. The adsorbent has to be organised on the composite such that it has the highest level of contact with sea water. The composite material needs to be reusable after it has adsorbed to its maximum. If it is not reused, the costs of production will be high.

Recently, T. S. Anirudhan and team from the University of Kerala proposed a new composite material for the adsorptive removal and recovery of uranium from seawater: a fibre with poly(acrylonitrile) on a chitosan/bentonite composite.

Bentonite is a clay mineral with large surface area, high cation exchange capacity and negative surface charge. Chitosan is a basic polysaccharide with a tendency to chelate metal ions.

The scientists conducted adsorption experiments with natural seawater from the Arabian Sea and found that the adsorbent has high efficiency in uranium extraction. The maximum adsorption capacity was nearly 50 milligrams per gram.

The scientists say that spent adsorbent can be reused after treatment with 0.1 M HCl and the adsorption capacity is good enough even after six cycles of adsorption–desorption. However, there is the probability that, in natural seawater, the absorption capacity might decrease due to competition with other ions for binding sites.

Large-scale production of uranium uses continuous pumping of large volumes of seawater. More than 10 feet of vertical pumping of seawater is not economically viable because the energy spent pumping will be more than the energy recovered from uranium. Thus, floating adsorbent systems may be more cost-effective for collecting uranium. And bentonite and chitosan are abundantly available. So, large scale deployment is feasible.

The material is also a candidate for removing uranium from groundwater.

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Lemon and Metal Nanoparticles

A recipe for water purification

India produces 130,000 tonnes of dyestuff annually. About one tenth of it sneaks into rivers with wastewater. Methylene blue, used in the textile industry, and rhodamine B, in the pharmaceutical industry, are the two most toxic pollutant dyes. Besides being highly toxic, the dyes are recalcitrant to biodegradation and persist in the environment for long.

With the help of a photocatalyst, visible light can decompose these toxins into simple benign chemicals. Recently, Navinchandra Shimpi and his colleagues at the University of Mumbai reported how photocatalytic nanoparticles of cadmium oxide – a semiconductor – can decompose the dyes efficiently.

The team synthesised the nanomaterial by adding lemon leaf extract to a mixture of silver nitrate and cadmium acetate. They used the ultrasonic cavitation technique to accelerate the reaction rate. The lemon extract acts as a reducing agent. It also works as a capping agent and thus stabilises the nanocomposite. Silver has high light absorption, photocatalytic and antimicrobial properties.

'Inducing electron-hole pairs in cadmium oxide by visible light gives it an edge over other semiconductors', says Navinchandra Shimpi, UM. 'Silver traps the electron and thus its doping into the cadmium oxide molecules reduces recombination of the electron-hole pairs' says his teammate Minakshi Jha.

Structural elucidation through spectroscopy and electron microscopy confirmed the formation of the silver : cadmium oxide crystals, of about 50 nanometers.

The tests showed that the nanocomposites could degrade 95% of methylene blue and 85% of rhodamine B at room conditions under visible wavelengths. The 5% silver-doped nanocomposite degraded methylene blue within 18 min and rhodamine in 24 min. The degradation of the dyes was evident from the shifting and reduction in the peak intensity of spectrophotometer readings.

What is the mechanism behind the degradation? Trapping experiments revealed that the highly reactive free oxygen species intermediates, produced by photocatalysis, were responsible for reducing the dye molecules. Carbon dioxide and water were the end products.

If the nanocomposite acted only as catalyst, then it is expected that it remains unaltered and thus could be reused. Indeed, the scientists found that the structure of the nanocomposite remained intact even after five cycles. And the degradation potential remained as high as 92%, compared to that of the freshly prepared catalyst.

Photocatalysis using sunlight is inexpensive and eco-friendly. Synthesis of the nanocomposite at room temperature and complete mineralisation of non-biodegradable dyes are the other strengths of the method. However, the system is operable on batch mode which is not practical for large scale treatment of wastewater. Converting it into a continuous flow reactor is still a challenge.

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Fertile with Possibilities

By-products to fertilisers

Grape crops and their industrial products are a major agro-economic activity worldwide. After grape juice

extraction, the by-products are discarded, contaminating water with organic loads.

Binoy K. Saikia, from the North East Institute of Science and Technology, Jorhat in collaboration with researchers from Colombia have now come up with a way to convert the waste by-product into agricultural fertiliser.

They mixed industrial wastes that could be complementary and supplementary to obtain high value products. They piled up pulpy residue and grapes for composting and, from the surface and interior parts of the base, as well as from the intermediate and top parts, they collected six aliquots from each pile at regular intervals. The aliquots were homogenised. Then, the team quarantined the solid samples in accordance with the Brazilian Reference Standard.

They separated the sampled materials: bagasse and stalks of white and black grapes. The crude liquid products obtained were homogenised in tanks and samples were collected. These were then packaged in containers.

The team took crude liquid samples from the collection tank. They also obtained a sampling of commercial packed products to verify quality. Using inductively coupled plasma optical emission spectrometry, they determined the major elements in the samples. The researchers oxidised the samples at high temperature, finely milled them and placed them in a tin capsule, which was free of carbon. After total combustion, the gases containing each element were separated and the concentration was measured using a thermal conductivity/infrared detector.

The scientists found that the residual material contained an adequate concentration of essential and important elements needed by plants.

'Based on our analyses, we found that grape industry by-products can be good raw material for promoting plant growth. They contain adequate levels of organic matter and essential growth elements. But, in the process of composting, the concentration of some elements, such as copper and chromium, increases. This acts as a limiting factor for manufacturers', says Binoy, CSIR-North East Institute of Science and Technology, Assam.

The solid compounds, by-products from the composting of different grape residues, help produce inputs that are useful for organic agriculture. However, they need to be mixed with other products with lower levels of copper and chromium and appropriate nutrients, say the scientists.

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Predicting Chikungunya

Model based on temperature

Chikungunya, transmitted by mosquitoes, first re-emerged in Delhi in 2016. And rapidly spread to new geographic regions causing long-term morbidity and even death. The chances of the virus spreading to other states were high. Since there is no specific antiviral drug, there is a need for surveillance.

Image: CDC Global Health via Flickr

Kakarla from the CSIR-Indian Institute of Chemical Technology, Hyderabad collaborated with scientists from the CSIR-Fourth Paradigm Institute, Bengaluru and the National Institute of Pharmaceutical Education and Research, Assam to tackle the problem. Last fortnight, they reported their investigations into the effect of temperature on the transmission of chikungunya, using a future predictive model.

The team gathered secondary data from primary infectious cases susceptible to vector transmission. They also took the mean surface air temperature dataset for the period of seventy years.

To develop the model, the researchers used the reproduction rate of the mosquitoes to predict epidemic dynamics of infectious diseases. Increasing temperature speeds up the life cycle of mosquitoes and enhances the feeding activity of vectors leading to the higher transmission rate. So they included the parameters sensitive to temperature: average blood meal frequency, vector to host and host to vector transmission of the chikungunya virus, extrinsic incubation period and mortality rate.

Using the model, they examined the temperature dependent dynamic transmission model to understand the transmission risk of the chikungunya virus. The model provided estimates of the effects of the temperature range for optimal transmission of chikungunya.

The team calculated the intensity of transmission using the reproductive rate for generating the model. For this, they used the average number of secondary infections caused by the chikungunya virus. Later, they tested the influence of climatic factors, such as temperature, for transmission at different seasons, so that strategic planning for disease and vector control operations could be implemented.

Their analysis with the temperature-driven model could predict the regions under risk for chikungunya transmission and regions for likely occurrence of disease outbreaks in India. 'Coastal areas and the southern region favoured chikungunya transmission. And, the central region and parts of the north and northeast regions showed low risk due to low-temperature', say Kakarla and his research team.

Their results also revealed a strong influence of seasonality in the outbreaks of chikungunya coinciding with the monsoon and early post-monsoon period.

Many parts of India have marked changes in seasonality. Hence, studies intending to develop a seasonal forecasting model for chikungunya are helpful. The model will also help predict the risk zones well in advance.

The scientists emphasise the need for continued surveillance to detect the chikungunya virus in the early stages of epidemics. They hope that the model will be an additional tool for healthcare preparedness.

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Checkmating Chronic Stress

Silencing the basolateral amygdala

Chronic stress plays havoc on all the systems of the body in various degrees. The primary region in the brain that deals with stress is the prefrontal cortex. The prefrontal cortex processes stimuli and responds by sending a signal to the basolateral amygdala. The basolateral amygdala responds by stimulating the hypothalamus-pituitary axis, leading to the release of stress hormones – the glucocorticoid hormones.

The stress hormones, in turn, stimulate the prefrontal cortex, which stimulates the basolateral amygdala. Adding to this vicious cycle, the basolateral amygdala also sends signals to the prefrontal cortex. These feedback loops strain the system which, ultimately, makes the prefrontal cortex thinner and the basolateral amygdala thicker. This leads to reduction in mental abilities, chronic anxiety and depression.

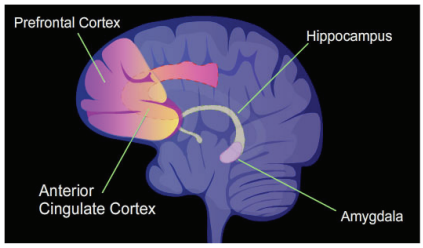

Image: NIH via Flickr

B. S. S. Rao and colleagues from the National Institute of Mental Health and Neuro Sciences, Bengaluru, wondered whether inactivating the basolateral amygdala could prevent the responses and subsequent damage associated with chronic stress.

To test this, they inactivated the basolateral amygdala of male Wistar rats by two different methods: injecting ibotenate infusion to induce lesions in the amygdala or injecting lidocaine, a local anaesthetic which temporarily inactivates the region.

The researchers subjected the rats to chronic immobilisation stress for two hours each day, for ten days. And gave them enough to eat and drink as they pleased.

In normal rats subjected to stress the relative body weight decreases, adrenal weight increases and there is hypertrophy of the spleen – typical biometric indices of stress induction. The team noted that, when subjected to stress, the rats with ibotenate infused lesions in the basolateral amygdala showed more relative body weight gain, less adrenal weight and hypertrophy of spleen than seen in normal rats.

They then examined changes in the six layers of the prefrontal cortex associated with severe stress and found decreased volume due to loss of neurons and increased dendritic volume.

Normal rats exposed to stress had reduced volume of layers I and II. But, in rats with lesions in the basolateral amygdala subjected to the same stress, the team found no such change in layers I and II.

The researchers observed that lesions of the basolateral amygdala minimised damage due to chronic stress. They evaluated the rats for stress-induced anxiety-like behaviour using Vogel's conflict test, where rats are subjected to mild shocks every 20th lick during their water intake. A healthy rat subjected to shock licked less and, thus, received fewer shocks. However, rats with lesions subjected to stress went on licking in spite of the shocks.

The scientists also found a correlation of chronic stress with the decreased volume of layer I of the prefrontal cortex. However, there was no such reduction of volume in layer I in rats with lesions in the basolateral amygdala subjected to chronic stress.

Lidocaine inactivates the basolateral amygdala only temporarily, unlike ibotenate. The researchers used lidocaine on rats and subjected them to both chronic immobilisation stress and shock test. They found that the drug reduces symptoms associated with stress and shock. Shankaranarayana says that partial silencing of the basolateral amygdala could alleviate symptoms of chronic stress.

An in-depth understanding of the histological changes in the brain associated with chronic stress in animal models gives us insights to combat chronic stress and anxiety in humans.

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Vehicular Pollution

Practices for a better future

The Indian automobile industry has grown by leaps and bounds over the years. It is also a major contributor to national income. But every coin has two sides: the increase in the number of vehicles on the road has led to vehicular pollution. In spite of the policies and norms set up by the government, it is becoming impossible to control the harm done to the environment by vehicular pollution.

Last fortnight, scientists from the CHARUSAT University, Changa and the Sardar Vallabhbhai National Institute of Technology, Gujarat reported their evaluative study on present policies to address this issue. They also explored practices that can be implemented in India and other developing countries to keep emissions under control.

The scientists examined the best practices that can help us follow the norms set: vehicle replacement, vehicle repowering and vehicle retrofitting.

In vehicle replacement, the old car is completely discarded and replaced with a new vehicle. In vehicle retrofitting, on the other hand, the same vehicle is used with emission control systems installed. Vehicle repowering is considered the most cost-effective of the three, as it involves changing engine and emission control devices to prolong vehicle life.

The scientists are confident that what they proposed can be used as guidelines by policy makers designing vehicle programmes. All three approaches, when implemented on vehicles, can significantly reduce emissions. And the vehicles would consume 0.5–8% less fuel than before.

The Indian Ministry of Road Transport and Highways has proposed Bharat Stage-VI, a policy to reduce particulate matter emission and to limit emission for various vehicle sizes. The practices proposed will

help reach these standards even for the older vehicles.

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Nano-based Solar Cell

An efficient dye-sensitised cell

Platinum based dye-sensitised cells are efficient and easy to fabricate. But expensive. So, platinum-free solar cells are the Holy Grail for researchers.

Last fortnight, scientists from the NIT, Tiruchirappalli in collaboration with the University of Salerno, Italy and the Feng Chia University, Taiwan reported fabricating an efficient nano based dye-sensitised solar cell that is free from platinum electrodes. The solar cell has titanium dioxide absorbing dye as photoanode and liquid iodine as electrolyte.

In dye-sensitised cells, the counter electrode plays a vital role in converting light energy into electrical energy. Instead of a platinum electrode, the scientists used corrosion-free molybdenum disulfide coupled with a reduced graphene oxide nanocomposite as counter electrode for their dye-sensitised solar cell.

The team found that the power conversion efficiency was more than eight percent. In contrast, the platinum based dye-sensitised solar cell had a power conversion efficiency of less than 7%. And all the relevant parameters – open circuit voltage, short circuit current and fill factor – were comparable to those of platinum based solar cells.

The researchers attribute the performance to the nanocomposite counter electrode that has higher electrical conductivity and the large surface area to the visible range light absorption. 'These two factors improve the electrocatalytic activity of the electrode and, hence, the device gets higher open circuit voltage, short circuit current and fill factor values', says S. Anandan, NIT, Tiruchirappalli.

The scientists caution that the annealing temperature should be chosen carefully while synthesising the electrode since molybdenum disulphide nanosheets yield alpha-molybdenum trioxide. They observed that the electrode, when annealed at 90°C for one hour, exhibits the best performance with a photon-to-current efficiency of more than 8%. Optimising the parameters might improve performance further, say the scientists.

So, in the future, these nano solar cells could replace platinum based solar cells to produce cheaper ones with better performance.

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Learning to See

Computer edition

Biological brains are hierarchical. Distinct neurons fire at subsystems to transform the flood of information into meaningful perceptions. The analogy is imperfect, but complex algorithms by the hippocampus and the cerebellum provide insights to develop machine learning. A handful of research groups are choosing the starting point: sense of vision.

Gautham Das, from the Amrita Vishwa Vidyapeetham, Coimbatore and his research peers from Europe analysed different machine learning methods to model the retina. Specifically, the ganglion cells. The group surgically removed a salamander retina and stimulated it with artificial white noise. They looked at the perturbations of computations performed by the retina. To measure the effects of this perturbation in the retinal output, the team used high density microelectrode arrays.

Vision starts in the retina, where photoreceptors receive these signals. Ganglion cells, the output neurons, then send the visual information to the brain. The visual cortex receives sensory data, processing information in 'strides'. Well-defined features like textures and colours are processed and passed like a pipeline.

'Machine learning systems create visual impressions over different layers', says Gautham. To process an image, the algorithm runs over the pixels, the output of one layer passed over to the next layer. The details about edges and textures and colours come together to shape an abstract prediction.

'Neuroscience and machine learning are still emerging', nods Gautham. The results of the group show that machine learning systems are getting better at transforming raw visual input into accurate guesses. These successive non-linear computations by machines can map patterns in abstractions, order in chaos. Often outperforming humans in these dynamic systems. Now that computers are driving cars, they better be as good as the eyes they are mimicking. The stakes have never been higher.

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