CHEMWATCH

Bulletin Board

Contents

MAR. 08, 2024

(click on page numbers for links)

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Contents

GOSSIP

CURIOSITIES

TECHNICAL NOTES

CHEMWATCH
Bulletin Board

Regulatory Update

MAR. 08, 2024

ASIA PACIFIC

Safe Work Australia has published a new report and corresponding snapshot which identifies trends in psychological health in Australian workplaces.

2024-02-27

The Psychological health and safety in the workplace report shows that during the latest reporting period of 2021-22p:

- Mental health conditions accounted for 9% of all serious workers' compensation claims, a 36.9% increase since 2017-18.
- The median time lost was more than 4 times greater than that of all physical injuries and illnesses.
- The median compensation paid for mental health conditions was more than 3 times greater than that of all physical injuries and illnesses.
- Workers with claims for mental health conditions experienced poorer return to work outcomes and were more likely to experience stigma from colleagues and their employers.

The report presents information on psychosocial hazards and health outcomes from Safe Work Australia's National Dataset for Compensation-based Statistics, the People at Work risk assessment survey and the National Return to Work survey.

It further supports the recently published updated WHS guidance relating to managing psychosocial hazards at work.

Download the full Psychological health and safety in the workplace report, or the overview snapshot.

Read More

Safe Work Australia, 27-02-24

https://data.safeworkaustralia.gov.au/report/psychological-health-and-safety-workplace

Proposed regulatory decision for neomycin

2024-02-27

The Australian Pesticides and Veterinary Medicines Authority (APVMA) has published its proposed decision for the reconsideration of neomycin,

an antibiotic contained in certain veterinary products for use in both companion and food-producing animals.

Neomycin was nominated for reconsideration due of concerns that the use of oral, intramammary and injectable preparations of neomycin, in accordance with the registered use pattern, could exceed the Australian maximum residue limits (MRLs). The proposed decision includes reconsideration of 9 neomycin products which are either oral, intramammary or injectable preparations and their associated labels.

The APVMA is proposing to:

- cancel 4 chemical product registrations and associated label approvals where no current uses can be supported
- vary and affirm 5 chemical product registrations and associated label approvals where at least one current use can be supported.

A summary of the underlying risk assessments and the product-specific assessment outcomes has been published in the Review Technical Report.

Public consultation on the proposed decision is open for 3 months and will close 26 May 2024. The APVMA Special Gazette, 27 February 2024 includes more information about the proposed decision and how to make a submission.

The APVMA will consider all submissions received during public consultation before making our final regulatory decision.

Read More

APVMA, 27-02-24

https://www.apvma.gov.au/news-and-publications/news/proposed-regulatory-decision-neomycin

Japan updates food contact materials positive list

2024-02-23

In late 2023, the Japanese Ministry of Health, Labor, and Welfare (MHLW) published a revised version of its positive list of substances for use in food contact materials (FCMs) available in both Japanese and English.

The positive list is divided into three documents: polymers, additives, and essential monomers each with relevant details including chemical name in Japanese and English, CAS registry numbers, and use requirements. The

CHEMWATCH
Bulletin Board
Regulatory Update
MAR. 08, 2024

updated list and any changes in requirements will go into effect on June 1, 2025.

According to reporting from Enhesa, MHLW plans to publish an FAQ on the website in the future.

Read More

FPF, 23-02-24

https://www.foodpackagingforum.org/news/japan-updates-food-contact-materials-positive-list

AMERICA

5-Day Emergency Public Notice and Comment Period

2024-02-27

Conditional Exemption for Undeployed Airbags

Department of Toxic Substances Control Reference Number: R-2023-21E

The Department of Toxic Substances Control (DTSC) proposes to adopt emergency regulations to amend the California Code of Regulations, title 22, division 4.5, sections 66260.10 and 66261.4. These changes are intended to facilitate the expedited removal and proper management of defective Takata airbags from vehicles and prevent their long-term storage to reduce the safety risk posed by the recalled airbag inflators.

Summary of Regulation Text

- Defines "airbag waste", "airbag waste collection facility", and "airbag waste handler"
- Excludes airbag waste from being subject to hazardous waste regulations at an airbag handler or during transport to an airbag waste collection facility or designated facility if certain conditions are met
- Subjects airbag waste to hazardous waste regulations once it arrives at an airbag waste collection facility or designated facility
- Prohibits the reuse of defective airbag modules or defective airbag inflators that are subject to a recall under the National Highway Traffic Safety Administration

Comment Period

DTSC intends to submit this proposed emergency action to the Office of Administrative Law (OAL) on March 4, 2024. The 5-day comment period will open when this proposed emergency action appears on OAL's list of Emergency Regulations Under Review.

Read More

alifornia Government, 27-02-24

https://oal.ca.gov/emergency_regulations/emergency_regulations_under_review/

UTAH - THE BEDDING, UPHOLSTERED FURNITURE AND QUILTED CLOTHING RULE (R70-101)

2024-02-02

Effective February 2, 2024, The State of Utah has temporarily repealed the online labeling rule for the law label online compliance under their Rule R70-101 for Bedding, Upholstered Furniture and Quilted Clothing. The state issued a Notice of Emergency (120 day) Rule.

The State of Utah repeal will temporarily pause the online labeling rule for the law label for bedding and furniture under the Emergency Rule. During this 120 day period, they will review with stakeholders and industry and make any necessary updates.

This will not change the rule regarding the textile labels for quilted clothing. Online labels will still be required for quilted clothing.

The textile label for quilted clothing is defined as a "tag attached to a quilted clothing product that provides information required in 16 CFR Parts 300, 301, 303 and this rule". It should be noted regulatory actions for the online quilted clothing will not be active during this time.

Read More

Bureau Veritas, 21-02-24

https://www.cps.bureauveritas.com/newsroom/update-utah-bedding-upholstered-furniture-and-quilted-clothing-rule-r70-101

CHEMWATCH
Bulletin Board
Regulatory Update
MAR. 08, 2024

EPA narrowing climate rule for power plants, saying it will take on more robust action later

2024-02-29

The Biden administration is narrowing its highly anticipated climate rule for power plants — dropping a proposed mandate for some existing gas plants to cut their emissions and instead saying it will tackle existing plants at a later date.

As part of its delay for existing gas plant rules, the agency said it will eventually propose a rule that covers the entire fleet — as opposed to just a fraction that would have been covered under its initial proposal.

But, in the meantime, it will only finalize climate pollution limits for existing coal plants and new gas plants, it announced Thursday. It is expected to finish the climate rule for new gas and existing coal power soon.

"This stronger, more durable approach will achieve greater emissions reductions than the current proposal," Environmental Protection Agency (EPA) Administrator Michael Regan said in a written statement.

While regulating the entire fleet of existing gas-fired power plants, instead of just some of them, would likely result in more climate benefits, whether the EPA is able to do so could ultimately depend on who wins the presidency this fall.

Read More

The Hill, 29-02-24

https://thehill.com/policy/energy-environment/4498669-epa-climate-rule-power-plants-carbon

EUROPE

Unexpected SVHC phthalate metabolite found in humans, including children

2024-02-28

In January 2024, the detection of an unexpected phthalate metabolite in samples from children aged 2 to 6 years was reported by the Federal State Office for Nature, the Environment and Consumer Protection in North Rhine Westphalia, Germany (LANUV). Over 60% of the 250 children tested

in 2020/21 had mono-n-hexyl phthalate (MnHxP, CAS 24539-57-9) in their urine.

These findings generated considerable media coverage across Germany (e.g., here, here and here) as MnHxP is a metabolite of di-n-hexyl phthalate (DnHxP, CAS 84-75-3), a substance of very high concern (SVHC) due to its reprotoxicity. In 2020, DnHxP was included in the EU REACH authorization list, essentially banning it in the EU unless one has special permission for its use. Since no applications for authorization were submitted, the detection of MnHxP was not anticipated and is a cause for concern due to its toxicity.

Analyses of samples retained from a study in 2017/18 showed that fewer children were affected in previous years (26% compared to 61% in 2020/21). The average MnHxP concentration was 0.28 µg/l in 2017/18, compared to 2.09 µg/l in 2020/21.

"It's a problem on a larger scale," said Marike Kolossa-Gehring, head of section toxicology and health related environmental monitoring at the German Environment Agency (UBA). Currently, additional human samples are being analyzed for MnHxP to understand time-trends and duration of exposure. Initial results show that MnHxP is detected in a significant proportion of the samples, which indicates widespread human exposure.

The exact sources of exposure to MnHxP in humans are currently unknown. One hypothesis under investigation is whether a UV filter used in sunscreen (diethylamino hydroxybenzoyl hexyl benzoate, DHHB, CAS 302776-68-7) has been contaminated with DnHxP, but other sources are being discussed.

Read More

FPF, 28-02-24

https://www.foodpackagingforum.org/news/unexpected-svhc-phthalate-metabolite-found-in-humans-including-children

Switzerland updates federal law on food contact materials and articles

2024-02-22

Updates to Switzerland's Ordinance on materials and articles intended to come into contact with food went into effect on February 1, 2024. The greatest change pertains to packaging inks; Part B of the positive list for packaging inks, listing unevaluated substances used in packaging inks

CHEMWATCH
Bulletin Board
Regulatory Update
MAR. 08, 2024

for food contact, has been removed. Substances not on the positive list or known to be carcinogenic, mutagenic, or toxic to reproduction are still allowed in packaging inks but subject to a generic detection limit of 0.01 mg/kg. Other amendments to the ordinance related to silicones, plastics, and ceramics bring Swiss regulation in closer alignment with that of the European Union (Regulation (EC) No 1935/2004).

The deletion of the list of unevaluated substances in packaging inks runs counter to movements elsewhere in Europe and the United States to increase transparency related to chemical use (FPF reported, also here). Removing sources of information on the chemicals used in food contact creates an added layer of difficulty to researchers investigating material safety. In the future, this may mean even basic inventories of intentionally used substances such as the Food Packaging Forum's food contact chemicals database (FCCdb), are less reliable.

According to FPF's database on migrating and extractable food contact chemicals (FCCmigex), 499 substances with CAS registry numbers have been detected in food contact printing inks. Only 55% (277) were previously known to be in printing inks according to the FCCdb.

Read More

FPF, 22-02-24

https://www.foodpackagingforum.org/news/switzerland-updates-federal-law-on-food-contact-materials-and-articles

INTERNATIONAL

FDA's new Quality Management System Regulation is here: Key takeaways for device companies in US, EU, and China

2024-02-19

On January 21, 2024, the FDA issued a final rule amending its Quality System (QS) regulations under 21 CFR Part 820, which addresses current good manufacturing practice (CGMP) requirements for medical device manufacturers. The amendments are aimed at more closely harmonizing these requirements with ISO 13485:2016, which is the international consensus standard for Quality Management Systems, as well as terms and definitions from Clause 3 of ISO 9000:2015, with some narrow exceptions set forth in the new 21 CFR 820.3(b).

The revised Part 820 is now referred to as the Quality Management System Regulation (QMSR). FDA's enforcement of the QMSR will begin on February 2, 2026.

In this alert, we discuss key takeaways from FDA's final rule as well as important considerations for the EU and China, where the ISO standard has been adopted in varying degrees.

Notable changes

In its public announcement, FDA expressed that ISO 13485:2016 is "substantially similar to the requirements of the current Part 820, providing a similar level of assurance in a firm's quality management system and ability to consistently manufacture devices that are safe and effective and otherwise in compliance with the [Federal Food, Drug, and Cosmetic Act]." Medical Devices; Quality System Regulation Amendments, 87 Fed. Reg. 36, at 10119 (Feb. 2, 2024) (final rule amending 21 CFR Part 820) (2022-03227.pdf (govinfo.gov)). FDA's amendments to Part 820 incorporate the ISO standard by reference and provide clarifications on specific areas to avoid inconsistencies between FDA's regulations and the ISO standard.

While principles and concepts described in the new QMSR are largely aligned with prior requirements under the old QS regulations, there are several differences worth noting.

- QMSR puts greater emphasis on risk-based decision making. The prior QS regulations had raised the concept of risk management in the context of design validation, but not other areas of the quality system. Under the QMSR, risk management is baked into the overall system, encouraging risk-based decision making throughout the total product lifecycle (ie, from design to market, and then post market). FDA elaborates specifically on this point in its response to comments on the final rule stating that "the more explicit integration of risk management throughout ISO 13485 and incorporated into the QMSR will help best meet the needs of patients and users and facilitate access to quality devices along with the progress of science and technology." Medical Devices; Quality System Regulation Amendments, 89 Fed. Reg. 23, at 7501 (Feb. 2, 2024) (FDA comments on final rule amending 21 CFR Part 820).

CHEMWATCH
Bulletin Board
Regulatory Update
MAR. 08, 2024

Read More

Lexology, 19-02-24

https://www.lexology.com/library/detail.aspx?g=8154e9e7-75b0-465f-8a04-458c0245e151

COP28 president urges countries to set plans for fossil fuel transition

2024-02-20

The United Arab Emirates, host of last year's COP28 climate summit, called on Tuesday for governments to take action in transitioning away from fossil fuels.

Intense negotiations last December saw countries agree to move away from fossil fuels in COP28's UAE Consensus document, aiming to limit the worst impacts of climate change. Now, nations must lay out plans for how they'll get there.

"We must now turn an unprecedented agreement into unprecedented action and results," COP28 president Sultan Al Jaber said on Tuesday.

Countries must update their plans to tackle climate change, known as nationally determined contributions or NDCs, said Al Jaber, who also leads the Abu Dhabi National Oil Company, at the Paris headquarters of the International Energy Agency.

The landmark 2015 Paris Agreement, which saw countries commit to try to limit global warming to 1.5 degrees Celsius (2.7F) above preindustrial levels, requires that countries update their NDCs every five years.

Read More

Reuters, 20-02-24

https://www.reuters.com/sustainability/climate-energy/cop28-president-urges-countries-set-plans-fossil-fuel-transition-2024-02-20/

ECHA checked over 20 % of REACH registration dossiers for compliance

2024-02-27

Since 2009, ECHA has evaluated nearly 15 000 registrations. The checks ensure that companies provide reliable information on the hazards of chemicals to support chemical safety in the European Union.

Helsinki, 27 February 2024 – The European Chemicals Agency (ECHA), between 2009 and 2023, has performed compliance checks of approximately 15 000 registrations, representing 21 % of full registrations. The Agency has met its legal target for dossier evaluation, which was increased from 5 % to 20 % in 2019. While, for substances registered at quantities of 100 tonnes or more per year, ECHA has checked compliance for around 30% of them.

In 2023, the Agency conducted 301 compliance checks, covering more than 1 750 registrations and addressing 274 individual substances. These checks focused on registration dossiers that may have data gaps and aim to enhance the safety data of these substances. As a result, 251 adopted decisions were sent to companies, requesting additional data to clarify long-term effects of chemicals on human health or the environment.

ECHA will now put more focus on following up the requests sent to companies. In the follow-up evaluation process, the Agency assesses the incoming information for compliance. The outcome of the incoming data is shared with the Member States and European Commission to enable prioritisation of substances. ECHA will work closer together with the Member States for enforcement of non-compliant dossiers.

Compliance of registration dossiers will remain a priority for ECHA for the coming years. This year, the Agency will review the impact of the Joint Evaluation Action Plan, aimed at improving REACH registrations compliance, and, together with stakeholders, develop new priority areas to work on. ECHA's workshop in March on its Integrated Regulatory Strategy will provide further input to this work.

Substance evaluation

In 2023, ECHA also adopted six substance evaluation decisions prepared by the EU Member States, requesting further information to assess the safety of substances of potential concern.

CHEMWATCH
Bulletin Board
REACH Update
MAR. 08, 2024

Joint Evaluation Action Plan

In 2019, ECHA and the European Commission decided on a joint plan to improve compliance of REACH registrations. The activities of the plan have now been completed. The next steps to further improve compliance of chemicals safety data are being discussed with the Commission, Member States and industry.

Read More

ECHA, 27-02-24

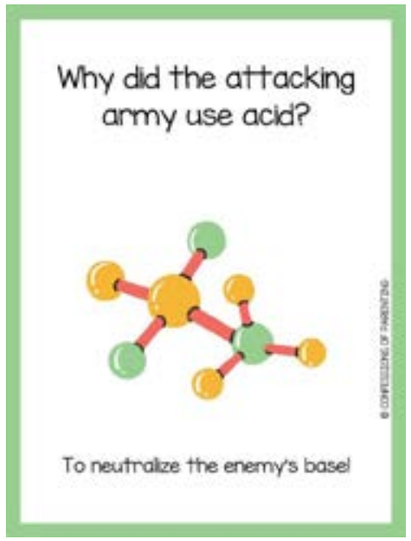
https://echa.europa.eu/-/echa-checked-over-20-of-reach-registration-dossiers-for-compliance-1

Janet's Corner

MAR. 08, 2024

Why did the attacking army use acid?

2024-03-08



https://www.voxopop.com/why-did-the-attacking-army-use-acid

CHEMWATCH
Bulletin Board

Hazard Alert

MAR. 08, 2024

Plutonium

2024-03-08

USES [2,3]

Plutonium is a key fissile component in modern nuclear weapons; care must be taken to avoid accumulation of amounts of plutonium which approach critical mass, the amount of plutonium which will self-generate a nuclear reaction. Despite not being confined by external pressure as is required for a nuclear weapon, it will nevertheless heat itself and break whatever confining environment it is in. Shape is relevant; compact shapes such as spheres are to be avoided. Plutonium could also be used to manufacture radiological weapons. The plutonium isotope 238Pu is an alpha emitter with a half-life of 87 years. These characteristics make it well suited for electrical power generation for devices which must function without direct maintenance for timescales approximating a human life time. It is therefore used in RTGs such as those powering the Galileo and Cassini space probes. Plutonium-238 was used on the Apollo-14 lunar flight in 1971 to power seismic devices and other equipment left on the Moon, and it was also the power supply of the two Voyager supercraft launched in 1977. Plutonium-239 can also be used as a fuel in a new generation of fast-breeder nuclear weapons, which burn a mixed oxide (MOX) fuel consisting of uranium and plutonium.

Plutonium is a trans-uranic radioactive chemical element with symbol Pu and atomic number 94. [1]

EXPOSURE SOURCES & ROUTES OF EXPOSURE [3]

Exposure Sources

- Everyone is exposed to very low levels of plutonium in air, and possibly in drinking water and food.
- Exposure to higher levels could occur from an accidental release during its use.
- Exposure during transport and disposal is unlikely because transport containers are virtually indestructible by accident or fire; disposal sites are deep underground and away from the public.
- Workers at nuclear facilities using plutonium may be exposed to higher levels of it.
- People who live near facilities that use plutonium in their operations may be exposed to it from accidental releases to the air.

Routes of Exposure

- Inhalation – The exposure route of primary concern for workers and the general population.
- Oral – Minor route of exposure.
- Dermal – Minor route of exposure

HEALTH EFFECTS [4]

Acute Health Effects

- The alpha radiation plutonium emits does not penetrate the skin, but can irradiate internal organs it is inhaled or ingested.
- Extremely small particles of plutonium on the order of micrograms can cause lung cancer if inhaled into the lungs.
- Considerably larger amounts may cause acute radiation poisoning and death if ingested or inhaled; however, so far, no human is known to have died because of inhaling or ingesting plutonium and many people have measurable amounts of plutonium in their bodies.
- When people breathe it in, plutonium may remain in the lungs or move to the bones or organs. Generally, it stays in the body for a long time and continually exposes body tissues to radiation. After a few years this could result in the development of cancer.
- Furthermore, plutonium may affect the ability to resist disease and the radioactivity from plutonium may cause reproductive failure.

SAFETY

First Aid Measures [5]

- **Inhalation**: Remove from exposure area to a restricted area with fresh air as quickly as possible. If breathing has stopped, perform artificial respiration by administering oxygen; mouth-to-mouth resuscitation should be avoided to prevent exposure to the person rendering first aid. Any evidence of serious contamination indicates that treatment must be instituted. (Inhalation of radioactive particles may indicate that other parts of the body were also contaminated, such as the digestive tract, skin and eyes.) If time permits, wipe the face with wet filter paper, force coughing and blowing of the nose. Get medical attention immediately. The victim may be contaminated with radioactive particles. Thorough decontamination should be started before the victim is moved to the medical area. Any personnel

CHEMWATCH
Bulletin Board
Hazard Alert
MAR. 08, 2024

involved in rendering first aid must be monitored for radioactivity and thoroughly decontaminated if necessary.
Skin Contact: Remove victim to a suitable area for decontamination as quickly as possible. Remove clothing and shoes immediately. Thoroughly wash the victim with soap and water, paying particular attention to the head, fingernails and palms of the hands. Upon completion of washing, monitor the victim for radioactivity. It is imperative that the skin should be decontaminated as quickly as possible. Minute skin injuries greatly increase the danger of isotope penetration into the victim; shaving should not be attempted. If water and soap have been inadequate in removing the radioactive compound, decontaminating compounds consisting of surfactants and absorbent substances may be effective. Complexing reagents may also be of use. The use of organic solvents is to be avoided, as they may increase the solubility and absorption of the radioactive substance. Skin contamination with radioactivity may be an indication that other parts of the body have been exposed. Contaminated clothing must be stored in an airtight, chemically compatible container for later decontamination or disposal. The water used to wash the victim must be stored in an airtight, chemically compatible container for later disposal. Any personnel involved in rendering first aid to the victim must be monitored for radioactivity and decontaminated if necessary.
Eye Contact: Remove victim to a restricted area for decontamination. Thoroughly wash eyes with large amounts of water, occasionally lifting the upper and lower lids (approximately 15 minutes). Following the water treatment, provide an isotonic solution. Do not use eyebaths, rather provide a continuous and copious supply of fluid. Monitor the victim for radioactivity. If activity is present, rewash the eyes, and remonitor until little or no radioactivity is present. Get medical attention immediately. Any water used to wash the victim's eyes must be stored in an airtight, chemically compatible container for later disposal. Any other articles that are used to decontaminate the victim must also be stored in similar containers for later decontamination or disposal. Any personnel involved in rendering first aid to the victim must be monitored for radioactivity and decontaminated if necessary.
Ingestion: In the case of ingestion of radioactive substances, the mouth should be rinsed out immediately after the accident, care being taken not to swallow the water used for this purpose. Vomiting should be induced either mechanically, or with syrup of ipecac.
Do not induce vomiting in an unconscious person. Lavage may be useful. Care should be taken to avoid aspiration. The vomitus and lavage fluids should be saved for examination and monitoring. Get

medical attention immediately. The gastric fluids and fluids used for lavage must be stored in airtight, chemically compatible containers for later disposal. The victim must be monitored for radioactivity and decontaminated, if necessary, before being transported to a medical facility. Any personnel involved in rendering first aid to the victim must be monitored for radioactivity and decontaminated if necessary.

Workplace Controls & Practices [4]

- At a minimum, provide process enclosure ventilation. Depending upon work activities, a more stringent ventilation system may be necessary to comply with exposure limits.
  A High Efficiency Particulate Air (HEPA) filtration system may be required for handling and storing this material.
  One method of controlling external radiation exposure is to provide adequate shielding. The absorbing material used and the thickness required to attenuate the radiation to acceptable levels depends on the type of radiation, its energy, the flux and the dimensions of the source.
  Alpha Particles: For the energy range of alpha particles usually encountered, a fraction of a millimetre of any ordinary material is sufficient for absorbance. Thin rubber, acrylic, stout paper, or cardboard will suffice.
  Beta Particles: Beta particles are more penetrating than alpha, and require more shielding. Materials composed mostly of elements of low atomic number such as acrylic, aluminium and thick rubber are most appropriate for the absorption of beta particles. For example, 1/4 inch of acrylic will absorb all beta particles up to 1 MeV.
  Gamma Rays: The most suitable materials shielding gamma radiation are lead and iron. The thickness required will depend on whether the source is producing narrow or broad beam radiation. Primary and secondary protective barriers may be required to block all radiation.
  Eye Protection: Employee must wear appropriate eye protection that will not allow the introduction of particles into the eyes. Contact lenses should not be worn.
  Clothing, glove and eye protection equipment will provide protection against alpha particles, and some protection against beta particles, depending on thickness, but will not shield gamma radiation.
  Clothing: Overgarments, including head coverings and foot covering, should be worn by any employee engaged in handling radioactive substances. These garments are also recommended even if the employee is working with a "glovebox" containment system. Certain clothing fibres may be useful in dosimetry so clothing should be kept.

CHEMWATCH
Bulletin Board
Hazard Alert
MAR. 08, 2024

In the event of an accident, large scale release or a large scale clean-up, full protective clothing will be necessary.
Gloves: Employee must wear appropriate protective gloves to prevent contact with this substance. Used gloves may present a radioactive contamination hazard and should be disposed of as radioactive waste.
Respirator: Respirators should provide protection for the respiratory tract against inhalation of most of the radioactive particles encountered in the workplace. Respirators will not offer protection against beta and gamma radiation, but will block alpha particles. Respiratory equipment must be jointly certified by NIOSH/MSHA. The following respiratory protection is recommended. Lower levels of protection may be appropriate depending on containment systems. Consult a qualified health physicist for more information.
General conditions: Type 'C' supplied-air respirator with a full face-piece operated in pressure-demand or other positive pressure mode or with a full face piece, helmet or hood operated in continuous-flow mode. Self-contained breathing apparatus with a full-face piece operated in pressure-demand or other positive pressure mode.
For firefighting and other immediately dangerous to life or health conditions: Self-contained breathing apparatus with full face piece operated in pressure-demand or other positive pressure mode. Supplied-air respirator with full face piece and operated in pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.

REGULATION

United States

The U.S. Nuclear Regulatory Commission (USNRC) has recommended the following radiation exposure limits for the general public and for workers:

General public	**0.1 rem/year for the general public and 0.5 rem/year for people who work with patients in nuclear medicine. These regulations are for all forms of radiation combined, so they are not only for plutonium.**
Workers	5 rem/year for workers in industries where exposure to radiation may occur and 0.5 rem for the pregnancy period following the declaration of pregnancy by a woman in an industry where exposure to radiation may occur.

These recommended radiation exposure limits are for all forms of radiation combined and are not specific to plutonium. The limits are expressed in units called rem (roentgen equivalent man). A rem is a radiation unit that expresses the radiation equivalent dose to a particular organ or tissue. The limits on equivalent dose are used to calculate the limits on the amount of radioactive substances that can be inhaled or ingested.

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CHEMWATCH
Bulletin Board

Broccoli Chemical Can Reduce Blood Clot Risk

2024-03-06

In pre-clinical trials, the study confirmed a natural chemical found in broccoli can reduce the formation of harmful blood clots that can in some instances lead to stroke, as well as improve the performance of clot-busting drugs afterwards.

Stroke is one of the five leading causes of death in Australia, claiming 23 lives every day.

Close to 55,000 Australians will suffer a stroke every year, often without warning, and this can happen at any age. About 85 per cent of strokes are caused by the formation of a harmful blood clot in the brain (also known as acute ischaemic stroke), which is a major cause of disability and costs an estimated $7.74 billion each year in health care in Australia.

Lead researcher Dr Xuyu (Johnny) Liu said the breakthrough paves the way for the development of new life-saving medications.

"After a patient has an ischaemic stroke, they are treated with tissue plasminogen activator (tPA), a type of clot busting medication to slow down the progression of damage to the brain. Unfortunately it is only successful in 20 per cent of cases," Dr Liu explained.

"What we found in a preclinical trial is that the tPA success rate increases to 60 per cent when the medication is given with the broccoli-derived compound. Excitingly, this naturally occurring compound does not cause any signs of bleeding, which is a common side effect associated with blood-thinning agents tested in stroke treatment.

"This means we could see paramedics treating ischaemic stroke patients with a broccoli-based medication as well as tPA on the way to hospital," he said.

The initial testing also showed that once the broccoli-derived molecules were administered they were also able to slow down the onset of a stroke.

"Not only is the broccoli compound effective in improving the performance of clot-busting medication after a stroke, it could be used as a preventative agent for patients who are at a high risk of stroke," said Dr Liu.

The broccoli breakthrough was the work of 25-year-old PhD student Ivy Guan, who works in the research team under the guidance of Dr Liu.

A three-year world-first study by the Heart Research Institute (HRI) has found that a common cruciferous vegetable eaten by millions of Australians every day could prevent and treat one of the nation's biggest killers.

Ms Guan said it's satisfying to make a discovery that has the potential to make such a difference.

"I was originally attracted to this project because I have a strong interest in the use of natural products as medicine," she said.

"A lot of the research I do is very limited to the lab, but this is something that can go out to the world and can impact people in normal, daily life and encourage people to be healthier."

The research team is now turning its attention to clinical trials, with the possibility of a new preventative and anti-clotting treatment for stroke being available in as little as five years.

Dr Liu believes the drug may have a wider use in diseases where blood clotting or thrombosis has a role.

"We are very excited at having isolated a natural compound that may have huge beneficial effects. Our studies will keep exploring how highly purified compounds from vegetables may have beneficial effects in disease processes.

"We want to understand how nature is giving us gifts to improve our health. Already we have discovered another compound from a different vegetable that looks promising in thrombotic diseases," Dr Liu said.

Technology Networks, 06 March 2024

https://technologynetworks.com

First synthetic protein motor creates its own fuel as it 'mows'

2024-02-27

"Imagine if a Roomba could be powered only by the dirt it picks up," said Nancy Forde, Simon Fraser University (SFU) physics professor and co-corresponding author of a study in which she and her fellow researchers outline their creation, a synthetic molecular motor that harnesses the energy of biological reactions to propel itself.

All living organisms, from humans to bacteria and plants, are kept alive by protein-based molecular motors that convert energy from one form into mechanical forces and motion that enable cell division, cargo delivery, movement towards food or light, and maintaining healthy tissues. SFU researchers, in collaboration with Lund University, Sweden, built on

The body uses protein-based molecular motors to perform functions essential to life. Now, researchers have created 'The Lawnmower,' the first synthetic motor modeled on those found in nature that propels itself by harnessing the energy it creates as it cuts through fields of proteins. It could transform our treatment of a range of diseases.

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

decades of research into the molecular motors seen in nature to realize their novel creation.

The Lawnmower could have important applications in medicine and biocomputing. The dysfunction of molecular motors in the neurons is related to many human neuronal diseases. Knowing how these motors work in healthy and diseased states may be key to understanding and treating motor neuron diseases like multiple sclerosis and spastic paraplegia. They could also be used for targeted drug delivery.

"Influenza is thought to work as a molecular motor to infiltrate the area around cells in order to infect them," said Forde. "Maybe synthetic motors could use the same approach, but rather than infecting cells, they could be engineered to deliver drug payloads to specifically target diseased cells."

The study was published in the journal Nature Communications.

New Atlas, 27 February 2024

https://newatlas.com

Scientists reveal molecular mysteries to control silica scaling in water treatment

2024-03-06

Silicon is the second most abundant element in the Earth's crust, and in natural water sources, it is commonly found in the form of dissolved silicic acid.

Under certain pH and temperature conditions in industrial feed water, the acid can become oversaturated and insoluble, precipitating a substance called silica scale that encrusts equipment. This unwanted coating fouls the surfaces of various engineering systems, such as reverse osmosis desalination water-treatment membranes, heat exchanger components, and plant pipelines.

"One way to combat the silica is to adjust the pH of the water, but this process is quite expensive and makes other forms of inorganic scalings, such as gypsum and calcite, worse," said ORNL's Vyacheslav "Slava" Bryantsev.

"Recently, people have been using silica-inhibiting polymers, or antiscalants, all of which are proprietary. We know these antiscalants are possibly a class of polyamine-type systems that somewhat impede

Collaborative research that combined experiments at Yale University and molecular dynamics simulations at the Department of Energy's Oak Ridge National Laboratory provides new insights into solving a major technical obstacle to efficient and sustainable industrial operations.

silica scaling, but how they work and how to improve on their existing properties have been poorly understood."

Previous studies on the performance of polymeric silica antiscalants have varied widely from hindering to accelerating the formation of silica scale. "Ours was the first systematic investigation into the role of molecular structures and functional groups of polymeric antiscalants in stabilizing oversaturated silicic acid solutions," Bryantsev said.

A paper titled "Molecular Design of Functional Polymers for Silica Scale Inhibition," published in Environmental Science & Technology, provides details of the study.

The Yale scientists synthesized a series of nitrogen-containing polymers as silica antiscalants and tested their performance in an oversaturated silicic acid solution. They discovered enormous differences in effectiveness among similar types of antiscalants.

"Working closely with our colleagues at ORNL, we were able to determine that the variations were due to the specific physical and chemical properties of the polymers," Yale's Masashi Kaneda said. "The approach and the outcome are notable because we provided an understanding of the mechanisms involved in mitigating silica scaling through the use of polymeric antiscalants in water treatment processes."

A polymer is a large molecule composed of repeating units, called monomers, that are linked together by chemical bonds to form a structural chain or backbone. As monomers containing functional groups engage in a polymerization reaction, they merge into a larger polymer, imparting distinct functionalities to the resulting structural chain.

Water-soluble chemical compounds called amines and amides are incorporated into polymers to form antiscalants because of their ability to stabilize and suspend silica. When a positively charged hydrogen ion is added to an amine molecule, the amine is said to be protonated. Protonation can increase the molecule's water solubility and reactivity.

In the Yale-ORNL study, the scientists discovered that polymers with charged amine and uncharged amide groups in their backbones exhibit superior silica scale inhibition performance, retaining up to 430 parts per million of reactive silica intact for eight hours under neutral pH conditions. However, monomers of these amine- and amide-containing polymers, along with polymers containing only amine and amide functionalities, presented insignificant inhibition.

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

"We needed to answer why the polymers we designed for the experiment worked while the monomers did not," said ORNL's Deng Dong. "To identify the design parameters, we conducted molecular dynamics simulations that we believed would enable us to understand the mechanisms behind the phenomena."

The simulations revealed strong binding between the deprotonated silicic acid and a polymer when the amine groups in the polymer were protonated.

"ORNL's contribution enabled us to discover that certain functional groups in the polymer chain synergistically contribute to the scale inhibition process," said Yale's Mingjiang Zhong.

Zhong added that silica scaling is quite different from other scaling processes.

"Although current efforts are focused on solving the silica scale problem through the water-treatment process, the ideal case will be to add one type of antiscalant to inhibit all types of scale formation, not just silica," Zhong said. "However, to the best of our knowledge, so far, there is no such antiscalant. The molecular understanding we gained from our research will guide us toward discovering a universal solution."

Phys Org, 06 March 2024

https://phys.org

Vaping Negatively Impacts the Sleep Quality and Anxiety Levels in Young Adults

2024-03-06

Researchers found that the sleep quality of vape users was significantly lower than that of their non-vaping peers, with more than three-quarters displaying symptoms of insomnia. The stimulative properties of nicotine could cause this poor sleep; also, sleep deprivation could increase vape use as a way to compensate for lethargy during the day.

Dr Simon Evans, Lecturer in Neuroscience at the University of Surrey, said: "It is now common to see a young person vaping. The emergence of vape shops makes these products more readily available and increases the temptation to purchase them. What is worrying is that many are unaware of or simply downplay the dangers of such products, believing that something that tastes 'fruity' could not be harmful. This is not the case as the nicotine contained in the products is known to negatively affect

Surrey researchers investigated the relationship between vaping, sleep quality and mental health of young adults aged 18-25 years. Researchers also investigated how vaping links to loneliness, and mindfulness (which can enhance emotional regulation).

brain development and may induce behaviours that increase the risk of developing substance abuse issues."

Vape use amongst young people has risen drastically over the last decade and not enough is known about its effects. To learn more, researchers surveyed 316 participants (263 who did not vape v 49 did) about their vaping habits, sleep quality and mental health. Importantly, anxiety levels were found to be heightened in the vape-user group, with 95.9 per cent of users being categorised as having clinical levels of anxiety symptoms.

Researchers also found that 73.5 per cent of those who vaped were evening types ('night owls') compared to only 40 per cent of non-users. Vape users also reported higher levels of loneliness. This loneliness might be linked to their 'night owl' tendencies, as previous studies have indicated that young adults who tend to stay up late at night often experience lower social support.

For the first time, researchers also examined levels of mindfulness and rumination. They found that vape users had significantly lower levels of mindfulness, and higher levels of rumination, than their non-user peers. This suggests that mindfulness training might help protect young people from taking up vaping. Conversely, those with higher levels of rumination could be vaping as a means to self-medicate against distress.

Dr Evans added: "Vaping impacts all areas of physical and mental health. Poor sleep not only affects a young person's daily functioning but, over the longer term, increases the risk of developing heart disease and diabetes. In this study, we found a disturbing link between vape use and anxiety symptoms, and it can become a vicious cycle of using a vape to soothe anxiety but then being unable to sleep, making you feel worse in the long run.

"However, the data shows that interventions that focus on mindfulness and combating rumination could be useful to reduce vape use amongst young people."

Technology Networks, 06 March 2024

https://technologynetworks.com

The Dutch 17th century master Rembrandt first laid down a lead-containing substance on his famous painting

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

Chemistry tools reveal surprise lead layer under a Rembrandt masterpiece

2023-12-22

The traditional way of preparing a canvas in the Netherlands in the 17th century involved animal glue, which has been documented to fail under humid conditions. But in The Night Watch there is no indication of a glue-size layer in any of the paint samples. Instead, the canvas appears to have been impregnated with a lead-containing oil.

Rembrandt probably used this previously unknown lead-rich layer below the quartz-clay ground layer of the canvas to serve as a protective barrier. The discovery sheds new light on Rembrandt's artistic techniques and is one of the first times this combination of synchrotron-based techniques has been used on a historic paint micro-sample.

The Night Watch was originally commissioned for the Kloveniersdoelen, which was a prominent shooting range in Amsterdam at the time, and it hung in a great hall on the long exterior wall-facing windows. To protect the painting from humidity, the authors hypothesise that the canvas was impregnated with the organic material containing lead, probably an oil, before Rembrandt began applying the ground layer of the painting.

This discovery not only reveals new insights into the composition and materials Rembrandt used to create The Night Watch, it also sheds light on his artistic process.

This work emerges from a massive research, restoration and conservation project called Operation Night Watch, which was initiated in 2019 by Rijksmuseum – the national museum of the Netherlands dedicated to Dutch arts and history – with the goal of the masterpiece's long-term preservation.

Chemistry World, 22 December 2023

https://chemistryworld.com

Aluminum nanoparticles make tunable green catalysts

2024-03-05

The Rice University lab of nanotechnology pioneer Naomi Halas has uncovered a transformative approach to harnessing the catalytic power of aluminum nanoparticles by annealing them in various gas atmospheres at high temperatures.

Catalysts unlock pathways for chemical reactions to unfold at faster and more efficient rates, and the development of new catalytic technologies is a critical part of the green energy transition.

According to a study published in the Proceedings of the National Academy of Sciences, Rice researchers and collaborators showed that changing the structure of the oxide layer that coats the particles modifies their catalytic properties, making them a versatile tool that can be tailored to suit the needs of different contexts of use from the production of sustainable fuels to water-based reactions.

"Aluminum is an earth-abundant metal used in many structural and technological applications," said Aaron Bayles, a Rice doctoral alum who is a lead author on the paper. "All aluminum is coated with a surface oxide, and until now we did not know what the structure of this native oxide layer on the nanoparticles was. This has been a limiting factor preventing the widespread application of aluminum nanoparticles."

Aluminum nanoparticles absorb and scatter light with remarkable efficiency due to surface plasmon resonance, a phenomenon that describes the collective oscillation of electrons on the metal surface in response to light of specific wavelengths. Like other plasmonic nanoparticles, the aluminum nanocrystal core can function as a nanoscale optical antenna, making it a promising catalyst for light-based reactions.

"Almost every chemical, every plastic that we use on a day-to-day basis, came from a catalytic process, and many of these catalytic processes rely on precious metals like platinum, rhodium, ruthenium and others," Bayles said.

"Our ultimate goal is to revolutionize catalysis, making it more accessible, efficient and environmentally friendly," said Halas, who is a University Professor, Rice's highest academic rank. "By harnessing the potential of plasmonic photocatalysis, we're paving the way for a brighter, more sustainable future."

The Halas group has been developing aluminum nanoparticles for plasmonic photocatalysis reactions such as decomposition of dangerous chemical warfare agents and efficient production of commodity chemicals. The newly uncovered ability to modify the surface oxides on aluminum nanoparticles further increases their versatility for use as catalysts to efficiently convert light into chemical energy.

"If you're doing a catalytic reaction, the molecules of the substance you're looking to transform will interact with the aluminum oxide layer rather than with the aluminum metal core, but that metallic nanocrystal core is uniquely able to absorb light very efficiently and convert it into energy,

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

while the oxide layer fulfills the role of a reactor, transferring that energy to reactant molecules," Bayles said.

The properties of the nanoparticles' oxide coating determine how they interact with other molecules or materials. The study elucidates the structure of this native oxide layer on aluminum nanoparticles and shows that simple thermal treatments -- i.e. heating the particles to temperatures of up to 500 degrees Celsius (932 Fahrenheit) in different gasses -- can change its structure.

"The crystalline phase, intraparticle strain and defect density can all be modified by this straightforward approach," Bayles said. "Initially, I was convinced that the thermal treatments did nothing, but the results surprised me."

One of the effects of the thermal treatments was to make the aluminum nanoparticles better at facilitating the conversion of carbon dioxide into carbon monoxide and water.

"Changing the alumina layer in this manner affects its catalytic properties, particularly for light-driven carbon dioxide reduction, which means the nanoparticles could be useful for producing sustainable fuels," said Bayles, who is now a postdoctoral researcher at the National Renewable Energy Laboratory.

Bayles added that the ability "to use abundant aluminum in place of precious metals could be hugely impactful to combat climate change and opens the way for other materials to be similarly enhanced."

"It was relatively easy to do these treatments and get big changes in catalytic behavior, which is surprising because aluminum oxide is famously not reactive -- it is very stable," Bayles said. "So for something that is a little bit more reactive -- like titanium oxide or copper oxide -- you might see even bigger effects."

The research was supported by the Air Force Office of Scientific Research (FA9550-15-1-0022), the Defense Threat Reduction Agency (HDTRA1-16-1-0042), the National Science Foundation (1449500, 1905757, 2239545), the Robert A. Welch Foundation (C-1220, C-1222, C-2065), the Department of Defense SMART Scholarship and Fulbright Colombia-Pasaporte a la Ciencia.

Science Daily, 05 March 2024

https://sciencedaily.com

Worried about microplastic particles in your tap water? Just boil it.

Concerned About Microplastics in Your Water? Consider Boiling It First

2024-02-28

At least, that's the suggestion put forward by researchers at Guangzhou Medical University and Jinan University, China.

In a new study, published in Environmental Science & Technology Letters, the team tested whether boiling your water might have any effect on the tiny nanoplastics and microplastics that are sometimes present in tap water. They found that boiling water effectively traps the plastic particles inside the limescale deposits that build up on a kettle's inner surfaces.

Could boiling your drinking water reduce exposure to microplastics?

Numerous studies have found evidence of microplastics in real-world tap water samples, but the health effects of ingesting microplastics from drinking water are still unclear. Early studies suggest these microplastics can accumulate in the body and affect the gut microbiome.

Despite the best efforts of water treatment plants, microplastics and nanoplastics remain tricky to remove from water using standard treatment methods. While there are some advanced water treatment technologies that can tackle this problem, they can be prohibitively expensive for less developed areas.

But what if a common household water treatment technique could already be slashing your exposure to microplastics?

"Drinking boiled water, an ancient tradition in some Asian countries, is supposedly beneficial for human health, as boiling can remove some chemicals and most biological substances," the researchers wrote. "However, it remains unclear whether boiling is effective in removing NMPs [nano- and microplastics] in tap water."

In their new study, the researchers used fluorescent particles of polystyrene plastic and examined how they behaved as they were heated in different types of water.

Boiling and filtering slashes microparticle levels by 90%

Tap water can either be considered "hard" or "soft", depending on how rich it is in calcium and magnesium minerals. These minerals are also responsible for the formation of limescale inside kettles, which is why

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

kettles need to be treated with descaler more frequently in areas with hard water.

The researchers found that when microplastic-containing water was brought closer to boiling temperatures, the added polystyrene NMPs began to co-precipitate out of the water alongside the minerals, becoming trapped in the crusty limescale deposits formed.

Technology Networks, 28 February 2024

https://technologynetworks.com

Metal-organic framework research makes key advance toward removing pesticide from groundwater

2024-03-06

Scientists led by an Oregon State University chemistry researcher are closing in on a new tool for tackling the global problem of weedkiller-tainted groundwater.

Kyriakos Stylianou of the OSU College of Science led an international team that identified a material known as a metal-organic framework, or MOF, that showed an ability to completely remove, and also break down, the oft-used herbicide glyphosate.

The MOF, one of four tested in a collaboration among scientists from Oregon State and Tiangong University in China, is based on scandium, chemical symbol Sc, and a carboxylate linker, TBAPy.

"When exposed to light for just five minutes, Sc-TBAPy eliminated 100% of glyphosate in water," Stylianou said. "In addition to its quicker adsorption and more efficient photodegradation of glyphosate compared to the other three TBAPy MOFs we looked at, it also degraded the glyphosate without producing a toxic acid, unlike the other three."

Findings were published in Nature Communications.

The MOFs in this experiment rely on photocatalysis. A catalyst is a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change, and photocatalysts are materials that absorb light to reach a higher energy level and can use that energy to break down organic contaminants through oxidation.

Among photocatalysts' many applications are self-cleaning coatings for stain- and odor-resistant walls, floors, ceilings and furniture.

Made up of positively-charged metal ions surrounded by organic linker molecules, MOFs are crystalline, porous materials with tunable structural

properties and nanosized pores. They can be designed with a variety of components that determine the MOF's properties.

Glyphosate, also known as N-phosphonomethyl glycine or PMG, has been widely sprayed on agricultural fields over the last 50 years since first appearing on the market under the trade name Roundup.

"Glyphosate and other herbicides are commonly used to safeguard farms from weed infestations, but the persistence of glyphosate in the environment has been associated with potential health effects on various living organisms including humans," Stylianou said.

"Only a small percentage of the total amount of PMG applied is taken up by crops, and herbicides leaching into water channels are a primary cause of water pollution. That means it's crucial to come up with innovative technologies and materials to combat this problem."

To uncover the PMG remediation abilities of Sc-TBAPy, Stylianou's lab collaborated with groups led by Chong Fang, Paul Ha Yeon Cheong and Hongliang Huang at Tiangong University. Stylianou said his collaborators provided key insights into the MOF's adsorption properties and photocatalytic activity.

A number of Oregon State graduate students also played important roles in the study, Stylianou said. Nan Chieh Chiu, Jacob Lessard and Emmanuel Musa led all the experiments and catalysis testing, Logan Lancaster investigated the optical properties of the materials being researched, and Clara Wheeler computationally examined their electronic properties.

OSU postdoctoral researcher Taylor Krueger, research associate Cheng Chen and graduate students Trenton Gallagher and Makenzie Nord also took part in the study.

Phys Org, 06 March 2024

https://phys.org

Making chemicals safe and sustainable

2024-03-04

As well as these everyday considerations, our industry has other, less predictable consequences. There are inherent hazards and risks, and when things go wrong, the impact can be enormous. Take, for example, the train derailment in East Palestine, US, in 2023, or the various fires, explosions, oil spills and leaks that make reasonably regular headlines around the

The concept of sustainability within chemistry and the chemicals industry has various aspects, and has evolved significantly over the decades.

CHEMWATCH
Bulletin Board
Gossip
MAR. 08, 2024

world. Because of their variable and unpredictable nature, the health and environmental cost of such incidents is rarely factored into the cost of producing those chemicals and using products derived from them.

It's impossible to completely eliminate such incidents. But we can prevent many, and lessen their impact when they do happen. Some of this mitigation can be achieved by innovations in processes around existing chemistry, but there are also opportunities to develop alternatives that are intrinsically less hazardous.

There is a cost barrier to changing any given process, and it's not something producers will undertake lightly. But it's clear that to meet commitments around climate and emissions, large numbers of products must be either replaced entirely or made more sustainably. And if processes, products and value chains are being redesigned, it makes sense to consider how to mitigate all aspects of their potential impact.

This is already a familiar concept and practice around much of the chemical industry. Process safety and continual improvement are backed by various industry programmes and external regulations. But there is potential value in making more explicit links between safety and other aspects of sustainability. In Europe, this approach is being integrated (as a voluntary guideline) into the EU's Chemicals Strategy for Sustainability, with the idea that chemicals should be 'safe and sustainable-by-design'.

As yet, that concept is only quite loosely defined. Cefic, the European Chemical Industry Council, suggests that criteria for evaluating chemicals 'must address the three pillars of sustainability – environmental, social and economic factors – and take a life cycle approach'.

This is a positive direction. However, as with other changes that are imposed by regulation and require investment, there is always a risk that businesses will shift to more lenient jurisdictions, rather than absorbing additional costs. The EU and UK are in the early stages of implementing measures to deter this kind of leakage for carbon emissions – it may be necessary to similarly protect other aspects of safety and sustainability.

Chemistry World, 06 March 2024

https://chemistryworld.com

National University of Singapore (NUS) chemists have solved a longstanding challenge in the synthesis of congested C(sp3)-rich molecules by developing a new iron-catalyzed reaction that generates two alkyl-alkyl bonds in crowded environments.

Earth-abundant iron catalysis enables access to valuable dialkylated compounds

2024-03-06

C(sp3)–C(sp3) bonds are single, strong bonds formed between two carbon atoms. They form the backbones of many biologically active natural products and synthetic molecules.

Research has shown that the number of saturated (sp3) carbons correlates with solubility, suggesting that increased saturation leads to enhanced potency and selectivity in drugs. However, developing methods to construct C(sp3)-rich scaffolds is an important but challenging goal in organic synthesis. This is because reactions involving sp3-hybridized substrates are typically inefficient and prone to undesired product formation.

A research team led by Associate Professor Koh Ming Joo, from the Department of Chemistry, NUS have conceived a new strategy that harnesses an earth-abundant (terpyridine) iron catalyst to combine alkenes with sp3-hybridized organohalides and organozinc reagents.

This approach allows them to add different-sized alkyl groups to the alkene, resulting in a library of drug-like molecules with congested cores containing either carbon- or heteroatom-substituted stereocenters. The method is useful for creating valuable but challenging C(sp3)-rich molecules.

This research is a collaboration with Dr. Xinglong Zhang from the Institute of High Performance Computing, Agency for Science, Technology and Research (A STAR) and Professor Patrick Holland from Yale University.

Prof Koh said, "Our studies suggest that this iron-catalyzed dialkylation reaction operates through a unique mechanism, which potentially opens the door to a wider range of transformations and new chemical space. This helps to diversify and broaden the chemical structures of performance molecules."

"We believe this method will accelerate the synthesis of many natural products and pharmaceuticals in a sustainable manner, especially those that contain densely functionalized alkyl-alkyl linkages," added Prof Koh.

CHEMWATCH
Bulletin Board

TB Vaccine Shrinks Liver Cancers in Mouse Study

2024-02-23

Hepatocellular carcinoma (HCC) is the most common type of liver cancer. It is also the third leading cause of cancer-related deaths worldwide. Current therapies include surgery, radiotherapy, chemotherapy, immunotherapy and liver transplant. Yet, the therapy outcomes for liver cancer remain bleak.

BCG, the century-old TB vaccine, is derived from the live bacteria Mycobacterium bovis. It is considered safe and widely used around the world.

BCG is also known to boost the body's immunity. The U.S. Food and Drug Administration has approved it for the treatment of bladder cancer. Yet, the potential effect of BCG in treating solid tumors, such as those of liver cancer, remained unknown.

The new study, led by Distinguished Professor Yu-Jui Yvonne Wan, showed that one dose of BCG delivered under the skin reduced tissue scarring (fibrosis), improved liver function, lowered liver lipid, and shrunk the tumor.

"HCC is very difficult to treat. This cancer is considered a cold tumor, which does not respond well to immunotherapy," said Wan, the study's senior author and vice chair for research in the UC Davis Department of Pathology and Laboratory Medicine. "We had a good reason to believe that the BCG vaccine could stimulate an immune response. So, we gave a dose of BCG to mice with liver cancer, and to our surprise, it was enough to activate the body's immune system and reduce tumor load."

How does the TB vaccine fight liver cancer?

The researchers gave a BCG dose under the skin to mice with liver cancer. This is the same way the BCG vaccine is given to humans. They found that BCG reduced inflammation and promoted the work of immune T cells. It specifically allowed the infiltration of CD4+ and CD8+ T cells and M1 macrophages into the tumor.

"We discovered that the BCG treatment resulted in the movement of T cells and macrophages to the tumor. It also activated the body's immunity and enhanced IFN-γ signaling, which contributes to an anti-HCC effect," Wan said.

A UC Davis Health study found that a single dose of Bacillus Calmette-Guérin (BCG), the vaccine for tuberculosis (TB), reduced liver tumor burden and extended the survival of mice with liver cancer.

Macrophages are white blood cells that can fight cancer. BCG induced IFN-γ signaling, resulting in cancer cell death.

The study also tested if the effects of BCG on liver cancer are sex dependent.

"While previous studies have shown sex differences in BCG effects on immunity, our data showed that both male and female HCC mice responded to the BCG treatment," Wan added.

A better immunotherapy for liver cancer

Bacterial immunotherapy, such as BCG, offers an alternative to current immunotherapy based on immune checkpoint inhibitors. It has the potential to revolutionize the treatment approach for HCC.

"Our study showed that BCG immunotherapy for HCC is different from and superior to other immunotherapies. It requires only a single injection. In animal models, BCG generated better anti-liver cancer treatment outcomes than other standard immunotherapies, such as anti-PD-1. This means a potentially more simplified treatment plan," Wan explained.

Future directions

The study findings suggest that the BCG vaccine could be repurposed as an HCC treatment. The discovery is significant, since BCG is already used safely around the world.

The researchers point to the need to explore the potential preventive ability of BCG and whether multiple doses would be even more effective at combating liver cancer. The efficacy could also be boosted through dosage adjustments, different timing and number of doses.

"If BCG treated a tough tumor like liver cancer, I'm optimistic it can work well on other hard-to-treat cancers. We would need more research to move to the next step. For example, we don't know how long this immune memory lasts, so efficacy of this vaccine over time is still a mystery. The mechanism can be complicated, and further research is needed," Wan explained.

The team also recommended examining the impact of BCG on the gut microbiome via the gut-liver axis.

Technology networks, 23 February 2024

https://technologynetworks.com

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

Using light to precisely control single-molecule devices

2024-03-05

The challenge

As devices continue to shrink, their electronic components must also be miniaturized. Single-molecule devices, which use organic molecules as their conductive channels, have the potential to resolve the miniaturization and functionalization challenges faced by traditional semiconductors. Such devices offer the exciting possibility of being controlled externally by using light, but -- until now – researchers have not been able to demonstrate this.

"With this work, we've unlocked a new dimension in molecular electronics, where light can be used to control how a molecule binds within the gap between two metal electrodes," said Latha Venkataraman, a pioneer in molecular electronics and Lawrence Gussman Professor of Applied Physics and professor of chemistry at Columbia Engineering. "It's like flipping a switch at the nanoscale, opening up all kinds of possibilities for designing smarter and more efficient electronic components."

The approach

Venkataraman's group has been studying the fundamental properties of single-molecule devices for almost two decades, exploring the interplay of physics, chemistry, and engineering at the nanometer scale. Her underlying focus is on building single-molecule circuits, a molecule attached to two electrodes, with varied functionality, where the circuit structure is defined with atomic precision.

Her group, as well as those creating functional devices with graphene, a carbon-based two-dimensional material, have known that making good electrical contacts between metal electrodes and carbon systems is a major challenge. One solution would be to use organo-metallic molecules and devise methods to interface electrical leads to the metal atoms within the molecule. Towards this goal, they decided to explore the use of organo-metallic iron-containing ferrocene molecules, which are also considered to be tiny building blocks in the world of nanotechnology. Just like LEGO pieces can be stacked together to create complex structures, ferrocene molecules can be used as building blocks to construct ultra-small electronic devices. The team used a molecule terminated by a ferrocene group comprising two carbon-based cyclopentadienyl rings that sandwich an iron atom. They then used light to leverage the electrochemical properties of the ferrocene-based molecules to form a

In a new Nature Communications study, Columbia Engineering researchers report that they have built highly conductive, tunable single-molecule devices in which the molecule is attached to leads by using direct metal-metal contacts.

direct bond between the ferrocene iron center and the gold (Au) electrode when the molecule was in an oxidized state (i.e. when the iron atom had lost one electron). In this state, they discovered that ferrocene could bind to the gold electrodes used to connect the molecule to the external circuitry. Technically, oxidizing the ferrocene enabled the binding of a Au0 to an Fe3+ center.

"By harnessing the light-induced oxidation, we found a way to manipulate these tiny building blocks at room temperature, opening doors to a future where light can be used to control the behavior of electronic devices at the molecular level," said the study's lead author Woojung Lee, who is a PhD student in Venkararaman's lab.

Potential impact

Venkataraman's new approach will enable her team to extend the types of molecular terminations (contact) chemistries they can use for creating single-molecule devices. This study also shows the ability to turn on and off this contact by using light to change the oxidation state of the ferrocene, demonstrating a light-switchable ferrocene-based single-molecule device. The light-controlled devices could pave the way for the development of sensors and switches that respond to specific light wavelengths, offering more versatile and efficient components for a wide range of technologies.

The team

This work was a collaborative effort involving synthesis, measurements, and calculations. The synthesis was done primarily at Columbia by Michael Inkpen, who was a post-doc in the Venkataraman group and is now an assistant professor at the University of Southern California. All the measurements were made by Woojung Lee, a graduate student in the Venkataraman group. The calculations were performed both by graduate students in the Venkataraman group and by collaborators from the University of Regensburg in Germany.

What's next

The researchers are now exploring the practical applications of light-controlled single-molecule devices. This could include optimizing device performance, studying their behavior under different environmental

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

conditions, and refining additional functionalities enabled by the metal-metal interface.

Science Daily, 05 March 2024

https://sciencedaily.com

Researchers use electrocatalysis for site-specific protein modification

22024-03-05

The team, led by BC professors of chemistry Abhishek Chatterjee and Eranthie Weerapana, developed and optimized a novel electrochemical protein labeling reaction called "eCLIC" that enables precise modification of site-specifically incorporated 5-hydroxytryptophan (5HTP) residues on many different proteins including full-length therapeutic antibodies.

Boston College researchers used a mild charge of electricity to precisely modify proteins, a new tool that can be used to develop novel biotherapeutics and protein-based research tools, the team reported recently in the journal Nature Chemistry.

"We used this strategy to generate many site-specific protein conjugates, including an antibody-cytotoxic drug conjugate that selectively enters and kills cancer cells, but not non-cancer cells," said Chatterjee. "A key advantage of eCLIC is the reagents needed for this method are really inexpensive, costing less than $10 a gram."

The team's success marked the first time electrocatalysis has been used to achieve protein modification in a site-specific manner, they reported in their article "Electrochemical labeling of hydroxyindoles with chemoselectivity for site-specific protein bioconjugation."

Proteins are large molecules, typically composed of hundreds of amino acid monomers, Chatterjee noted. The ability to selectively modify proteins at predefined sites is important for many applications. For example, by covalently attaching toxic drugs to antibodies it has been possible to selectively deliver them to cancer cells, which resulted in both improved therapeutic efficacy and reduced off-target toxicity.

Many research applications also require the attachment of biophysical probes onto various proteins. The ability to define the site of modification on proteins is critical to ensure that important protein functions are not harmed, Chatterjee said.

"The challenge arises from the fact that all proteins are made from 20 amino acids in various combinations," he said. "Identifying a modifiable functionality at the desired site, not repeated elsewhere, is typically challenging, which makes it difficult to achieve site-specificity in protein modification."

To overcome these challenges, the team sought to develop a method to incorporate a non-natural amino acid at any chosen site(s) of a protein. The team accomplished this by reengineering the translation system of cells to accommodate the new amino acid 5HTP.

In addition, the researchers wanted to design chemical reactions that could be used to selectively modify this nonnatural amino acid in the presence of all of the natural amino acids, Chatterjee said.

"If we could do this, we could provide a general method to generate proteins with a built-in 'attachment-handle' at a predefined site. In particular, we were interested in developing a reaction that would use electricity to catalyze the protein modification reaction instead of chemical catalysis since the former is inexpensive, environmentally friendly, and gentle on delicate proteins."

Chatterjee said the team was able to overcome an unusual challenge when they first tried to model the reaction. Typically, researchers start with small molecules, in this case, 5HTP and aniline, then move on to large proteins.

But first attempts at the reaction between 5HTP and anilines at the small-molecule level were messy, as the 5HTP molecules reacted preferentially with each other. But when 5HTP was incorporated into a large protein, it was no longer able to react with another protein-bound 5HTP and cleanly reacted with an aniline instead, the team reported.

"If we had stuck with the traditional progression—from small to large—we'd have never pursued eCLIC, thinking 'it's too messy'," Chatterjee said. "Instead, we did our reaction development non-traditionally, directly on a protein, which helped us realize how clean and selective it was in this setting."

To further advance the eCLIC strategy for large-scale modification of important protein targets, this technology has been licensed toBrickBio, Inc., which Chatterjee co-founded. Future research will focus on developing next-generation, site-specifically modified protein-based biotherapeutics and research reagents.

Phys Org, 05 March 2024

https://phys.org

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

Barnacle proteins protect metals from corrosion in salt water

2024-03-05

Metal surfaces of boats and offshore rigs are coated with corrosion-inhibiting compounds to protect them in the high-salt environment of the sea. Commercial inhibitors are organic compounds based on azoles, amines, and phenols. They form tough films on metal surfaces, preventing exposure to seawater, but they can leach toxic chemicals into the environment, harming living organisms.

Because barnacles cling to underwater metal surfaces, researchers at Nanyang Technological University investigated whether the crustaceans' adhesive proteins could form an impenetrable protective layer on metal.

The team genetically engineered bacteria to produce a recombinant protein of the barnacle Megabalanus rosa. Other researchers have made glues for bone or dental repair from this protein because it adheres strongly to inorganic substrates, says materials scientist and engineer Ali Miserez, who led the work.

The researchers immersed steel pieces in a concentrated salt solution that simulated seawater, and they added protein solutions of different concentrations. At concentrations over 5 mg/mL, the protein quickly adsorbed onto the steel surface to form a uniform layer. Spectroscopy analysis and computer simulations suggested that the protein formed a complex with free iron ions in the steel. "This complex effectively covers the metal substrate, preventing corrosion," Miserez says.

"This is high-risk, high-reward work," says Nick Aldred, who studies bioinspired coatings at the University of Essex. "It may not work, but if it does, the impact will be large." A big challenge with biomaterials is that "protein layers tend to become food for bacteria very quickly," he says, so it will be important to engineer proteins that do not quickly degrade in the environment.

C&EN, 05 March 2024

https://cen.com

Mussels, barnacles, and other sticky marine invertebrates have been many a researcher's inspiration for designing novel adhesives.

Earth-abundant iron catalysis enables access to valuable dialkylated compounds

2024-03-06

C(sp3)–C(sp3) bonds are single, strong bonds formed between two carbon atoms. They form the backbones of many biologically active natural products and synthetic molecules.

Research has shown that the number of saturated (sp3) carbons correlates with solubility, suggesting that increased saturation leads to enhanced potency and selectivity in drugs. However, developing methods to construct C(sp3)-rich scaffolds is an important but challenging goal in organic synthesis. This is because reactions involving sp3-hybridized substrates are typically inefficient and prone to undesired product formation.

A research team led by Associate Professor Koh Ming Joo, from the Department of Chemistry, NUS have conceived a new strategy that harnesses an earth-abundant (terpyridine) iron catalyst to combine alkenes with sp3-hybridized organohalides and organozinc reagents.

This approach allows them to add different-sized alkyl groups to the alkene, resulting in a library of drug-like molecules with congested cores containing either carbon- or heteroatom-substituted stereocenters. The method is useful for creating valuable but challenging C(sp3)-rich molecules.

This research is a collaboration with Dr. Xinglong Zhang from the Institute of High Performance Computing, Agency for Science, Technology and Research (A STAR) and Professor Patrick Holland from Yale University.

Prof Koh said, "Our studies suggest that this iron-catalyzed dialkylation reaction operates through a unique mechanism, which potentially opens the door to a wider range of transformations and new chemical space. This helps to diversify and broaden the chemical structures of performance molecules."

"We believe this method will accelerate the synthesis of many natural products and pharmaceuticals in a sustainable manner, especially those that contain densely functionalized alkyl-alkyl linkages," added Prof Koh.

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

The research team is leveraging the newly discovered iron-catalyzed system to transform other classes of organic starting materials into useful compounds for various applications, including drug development.

Technology Networks, 06 March 2024

https://technologynetworks.com

Yale Chemists Synthesize Elusive Anticancer Molecules

2024-03-06

The chemical structures of these molecules, which consist of a dense, highly complex knot of oxidized rings and nitrogen atoms, have attracted the interest of organic chemists worldwide, who aimed to recreate these structures from scratch in the laboratory. However, despite considerable effort, it has remained an elusive task. Until now, that is.

A team of Yale chemists, writing in the journal Science, has succeeded in synthesizing eight of the compounds for the first time using an approach that combines inventive chemical strategy with the latest technology in small molecule structure determination.

"These molecules have been an outstanding challenge in the field of synthetic chemistry," said Seth Herzon, the Milton Harris '29 Ph.D. Professor of Chemistry in Yale's Faculty of Arts and Sciences and corresponding author of the new study. "A number of research groups have tried to recreate these molecules in the lab, but their structures are so dense, so intricately connected, that it hasn't been possible. I've been reading about efforts to synthesize these compounds since I was a graduate student in the early 2000s."

In nature, the molecules are found in some species of bryozoa — small, aquatic animals that feed by filtering prey from the water via tiny tentacles. Researchers worldwide consider bryozoans to be a potentially valuable source of new medications, and many molecules isolated from bryozoans have been studied as novel anticancer agents. However, the complexity of the molecules often limits their further development.

Herzon's team looked at a particular species of bryozoa called Securiflustra securifrons.

"We worked on these molecules about a decade ago, and though we were not successful in recreating them at that time, we gleaned insight into their structure and chemical reactivity, which informed our thinking," Herzon said.

Almost three decades ago, researchers identified a distinct group of anticancer compounds within bryozoans, a category of marine invertebrates native to tropical waters.

Innovative Chemical Strategies

The new approach involved three key strategic elements. First, Herzon and his team avoided constructing a reactive heterocyclic ring, known as an indole, until the end of the process. A heterocyclic ring contains two or more elements — and this specific ring is known to be reactive and create problems, Herzon said.

Second, the researchers used methods known as oxidative photocyclizations to construct some of the key bonds in the molecules. One of these photocyclizations involved the reaction of a heterocycle with molecular oxygen, which was first studied by Yale's Harry Wasserman in the 1960s.

Lastly, Herzon and his team employed microcrystal electron diffraction (MicroED) analysis to help visualize the structure of the molecules. Herzon said conventional methods for structure determination were inadequate in this context.

The result of the new approach is eight new synthetic molecules with therapeutic potential — and the promise of more new chemistry to come.

"These molecules hit right at my love of complex synthetic challenges," said Herzon, who is also a member of the Yale Cancer Center and holds joint appointments in pharmacology and therapeutic radiology at Yale School of Medicine. "On a molecular weight basis, they are modest relative to other molecules we've studied in my lab. But from the vantage point of chemical reactivity, they present some of the greatest challenges we've ever taken on."

SciTechDaily, 06 March 2024

https://scitechdaily.com

3M pledges to stop making and using "forever chemicals" by 2025

2023-12-23

Used in everything from non-stick cookware, water-repellent clothing, electrical wiring insulation, shampoo, stain resistant fabrics and carpets, to cosmetics and firefighting foams, PFAS chemicals have been used in consumer products and industry worldwide since the 1940s.

However, over the years, many of these versatile PFAS compounds have been identified as having toxic and persistent properties, and links to a wide range of health issues have been found, including changes in liver enzymes, an increased risk of some cancers, reduced fetal growth and reduced ability of the immune system to fight infections.

US manufacturing firm 3M has said it will stop making and using PFAS, a group of over 4700 industrial chemicals commonly known as "forever chemicals", across its product range by the end of 2025.

PFAS are formed by a chain of linked carbon and fluorine atoms, and are referred to as either 'short-chain' or 'long-chain' depending on the chain length; short-chain PFAS are generally non-polymers with 6 or less atoms making up the chain, long-chain varieties on the other hand refer to non-polymers with 7 to 13 atoms.

Regardless of chain length however, the carbon-fluorine bond which has made PFAS so useful is also what has led this group of compounds to be called "forever chemicals" because the carbon-fluorine bond is one of the strongest, meaning these chemicals do not degrade easily.

Such is their persistence that the half-lives of some PFAS polymers is estimated to be greater than 1,000 years in soil and over 40 years in water. This chemical stability poses bioaccumulation problems and studies have shown that PFAS can bind to proteins, for example in blood, and over time can build up in brain, liver, lung, bone, and kidney tissue, if people take in more of the chemicals than they excrete.

Some countries have already phased out long-chain PFAS and replaced them with short-chain varieties, but these too are proving to be more toxic than previously thought.

3M said it has already reduced its use of PFAS over the past three years through ongoing research and development, but will now look to discontinue manufacturing all fluoropolymers, fluorinated fluids, and PFAS-based additive products by the end of 2025.

"This helps position our company for sustainable growth by optimizing our portfolio, continuing to innovate for our customers, and delivering long-term value for our shareholders," 3M said.

It's a timeframe that is based partly on restriction proposals put forward to the European Chemicals Agency (ECHA) by Denmark, Germany, Norway, Sweden and the Netherlands to ban PFAS across Europe by the end of 2025.

Health and environment bodies in the UK have also called on the government to ban PFAS, however a damning report earlier this year suggests that although various plans to address and evaluate options

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for the chemicals were put forward, no formal restriction process was triggered for any of the PFAS mentioned in the report.

The Chemical Engineer, 23 December 2024

https://thechemicalengineer.com

Chemists break barriers and open up super-resolution molecule mass analysis

2024-03-06

The precision upgrade is comparable to measuring a mass difference of one in a million. Heck compares it to a bag of sugar. "This precision relates to being able to tell that one sugar grain is missing from a full bag of 1 kilogram of sugar", says Heck.

The team published their results today in the journal Nature Methods. Their massive resolution upgrading could benefit the fabrication of vaccines and molecular vectors used in gene therapy.

A thousand times longer

Traditionally, chemists use a technology called mass spectrometry to examine the composition of molecules. Although this offers analyses in substantial levels of detail, its downside is that it looks at millions of molecules at once. This makes it tricky to study large molecules because the higher number of trapped molecules interfere with each other.

So, they developed a new method whereby just a single molecule is trapped in a so-called Orbitrap while heavily spinning. By measuring the spinning behavior, they are able to analyze the mass and composition of the molecule.

Normally, this method can only record signals for a short duration, typically around 25 milliseconds. In their study, the scientists modified the data acquisition method, allowing them to trap and monitor individual ions a thousand times longer, for up to an impressive 25 seconds.

To understand this advancement, imagine swinging on a swing for just a few seconds versus swinging for a prolonged period. The longer you swing, the more accurately an observer can measure your rhythm and deduce characteristics about you. Similarly, by trapping spinning ions for an extended duration, scientists can capture more detailed information about their spinning frequency and thus better characterize molecules.

A team of chemists led by Prof. Albert Heck puts a new spin on analyzing and understanding molecules.

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

Being able to measure giant molecules in such detail could pave the way for advancements in various fields, says Heck. One example is the production of therapeutic molecules, such as viruses, clinically used in gene therapy. These viruses are loaded with a human correctly functioning gene that replaces erroneous genes in the DNA of patients suffering from a genetic disorder.

Heck says, "Up until now, developers of gene therapy viruses cannot really verify if a virus harbors the specific gene that it is supposed to deliver. It is estimated that by current methods, only 1 to 2 percent of the produced gene therapy viruses are successfully loaded with the desired gene. This induces o that a substantial part of the therapeutic viruses introduced in a patient will have no effect."

If gene therapy developers can better measure the difference between 'empty' versus 'filled' viruses, they could make their production lines more efficient. Heck says, "When you consider that some of the gene therapy treatments cost around 1 million euros per treatment, this efficiency improvement could have a significant beneficial impact."

Phys Org, 06 March 2024

https://phys.org

Turning Waste Into Wonder: A Breakthrough in Pollution Control

2024-02-28

Polychlorinated dibenzo-p-dioxins and dibenzofurans are dangerous pollutants due to their carcinogenicity and persistence in the environment. Traditional catalytic oxidation methods for their removal face challenges like high cost and inefficiency at lower temperatures. Research has shown that using carbon materials, such as carbon nanotubes and active carbons, improves catalytic performance by enhancing the adsorption and distribution of active sites.

However, their application is limited by costs and maintenance issues. N-doped carbon materials, derived from biomass, offer a promising alternative with their high surface area and porosity, potentially lowering operational temperatures and increasing efficiency.

Breakthrough in Catalyst Development

In a new study recently published in the journal Waste Disposal & Sustainable Energy, researchers from Zhejiang University, introduces a

Scientists have achieved notable progress in reducing environmental pollution by improving the performance of vanadium-based catalysts with nitrogen-doped biomass carbon.

catalyst combining vanadium-based components and nitrogen-doped biomass carbon (NHPC). This development significantly enhances the low-temperature degradation activity of furan, offering a novel solution for the efficient breakdown of persistent organic pollutants, marking a significant step forward in environmental remediation efforts.

In this study, researchers developed a series of vanadium-based catalysts, and their catalytic performances were significantly enhanced by nitrogen-doped hierarchical porous carbon (NHPC) derived from biomass. This enhancement led to a marked improvement in the degradation of furan, a persistent organic pollutant, at lower temperatures than previously possible. The NHPC's introduction into the catalyst structure facilitated an increase in active sites and improved the homogeneous distribution of vanadium oxide phases, which are crucial for the catalytic process. At 150 °C, the modified catalyst achieved 50% furan conversion, a significant improvement over traditional catalysts, with complete conversion occurring at 200°C.'

Sustainable Environmental Remediation Techniques

Dr. Minghui Tang, a leading researcher in the study, states, "This breakthrough not only enhances the efficiency of furan degradation at significantly lower temperatures but also opens new pathways for sustainable environmental remediation techniques."

The application of N-doped Hierarchical Porous Carbon (NHPC) in catalysts marks a pivotal advancement in environmental technology, offering a low-temperature, cost-effective method for hazardous pollutant removal. This innovation not only sets a new standard for pollution control but also underscores the potential of biomass-derived carbon materials in catalytic degradation., enhancing pollutant degradation efficiency and fostering sustainable environmental protection solutions.

C&EN, 28 February 2024

https://cen.com

Chemical Reactor Uses Microwaves to Reduce Carbon Emissions

2024-02-17

Lead researcher John Hu is the Statler Chair in Engineering for Natural Gas Utilization at the WVU Benjamin M. Statler College of Engineering and Mineral Resources, a professor of chemical engineering and director of the

West Virginia University engineers have received $3 million in U.S. Department of Energy funding for researching a novel chemical reactor system utilizing microwaves to reduce industrial heat and carbon emissions.

CHEMWATCH
Bulletin Board
Curiosities
MAR. 08, 2024

WVU Center for Innovation in Gas Research and Utilization. Hu emphasized that, while the study focuses on ethylene and ammonia production, the technology can be broadly applied to many other industrial processes that need heat to work.

"Using microwaves allows us to control the heat delivery very precisely, so that we can quickly switch between heating the reactor to produce methane and cooling it to synthesize ammonia," Hu said in a Feb. 15 press release. "By using the hydrogen from methane coupling, we remove the need for a hydrogen production step in ammonia synthesis and make the process much more friendly to the environment."

Chemical Processing, 17 February 2024

https://chemicalprocessing.com

CHEMWATCH

Bulletin Board

Technical Notes

MAR. 08, 2024

(NOTE: OPEN YOUR WEB BROWSER AND CLICK ON HEADING TO LINK TO SECTION)

CHEMICAL EFFECTS

Indoor metabolites and chemicals outperform microbiome in classifying childhood asthma and allergic rhinitis

Hydrogen inhalation: in vivo rat genotoxicity tests

High toxicity of agro-industrial wastewater on aquatic fauna of a South American stream: Mortality of aquatic turtles and amphibian tadpoles as bioindicators of environmental health

ENVIRONMENTAL RESEARCH

Airborne Suspended Particulate Matter and the Prevalence of Allergic Conjunctivitis in Japan

Taurine induces hormesis in multiple biological models: May have transformative implications for overall societal health

PHARMACEUTICAL/TOXICOLOGY

The association of fatigue and cognitive complaints with work-related outcomes and cancer-related anxiety among employees 2-10 years after cancer diagnosis

Metals, nonmetals and metalloids in cigarette smoke as hazardous compounds for human health

OCCUPATIONAL

Association Between Augmentation Index and Total Sleep Time in Night Shift Workers

The Effects of Heat Stress on Bakery Workers: A Systematic Review

Airway diseases related to the use of cleaning agents in occupational settings