JOURNAL ARTICLE WATCH

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In this issue, the CWMD Journal will introduce a new section spotlighting policy and scientific research of interest to the countering weapons of mass destruction (WMD) community. The importance of staying up to date on new research in this area cannot be overstated. Advancements in biological, chemical, nuclear, and policy research have far-reaching implications for global security and the well-being of nations. This section aims to provide our readers with a comprehensive overview of the latest breakthroughs, emerging technologies, and policy developments with relevance to countering WMDs. From cutting-edge research on nonproliferation strategies to innovative detection methods, we will explore the diverse facets of this critical field. Read on for in-depth analysis of ongoing research and thought-provoking pieces that shed light on the challenges and opportunities related to countering WMDs.

THE COMPLEXITIES OF CHINA'S CHANGING NUCLEAR POSTURE

SUMMARY OF RESEARCH:

China's strategic community is expressing heightened concerns about its external security environment, primarily due to evolving dynamics in its relationship with the United States. These concerns arise from a complex entangled security dilemma characterized by three key pathways: 1) China's perception that the U.S. is lowering the threshold for using nuclear weapons to compensate for conventional weaknesses in East Asia, 2) worries about the U.S.'s development of advanced conventional capabilities that undermine China's secure second-strike capability, and 3) China's efforts to employ advanced conventional weapons to defeat U.S. missile defenses. Despite these concerns, there is little evidence that China is shifting away from its strategy of assured retaliation, though changes in its approach to securing its nuclear deterrent may emerge over time. This entangled security dilemma is impacting U.S.-China relations, influencing nuclear threat perceptions, and exacerbating the security dilemma.

WHY IT MATTERS TO CWMD:

The evolving U.S.-China security dynamic, as described in the passage, has significant implications for global security. The entangled security dilemma between these two major powers increases the risk of arms race pressures, particularly in the nuclear realm. China's efforts to bolster its nuclear capabilities, combined with its concerns about U.S. military developments, could lead to a potentially destabilizing nuclear competition. This not only affects regional security but also has broader consequences for international arms control efforts.

Moreover, the passage underscores the challenges of engaging China in nuclear arms control. China's suspicions about U.S. capabilities and the entangled security dilemma make it unlikely that China would agree to arms control measures solely focused on nuclear capabilities. The inclusion of conventional capabilities further complicates negotiations. As a result, the world may witness an arms race between the U.S. and China, fueled by the entangled security dilemma and shifting military balances in the Asia-Pacific region. This could have profound ramifications for global stability and arms control efforts in the future.

REFERENCE:

Henrik Stålhane Hiim, M. Taylor Fravel, Magnus Langset Trøan; The Dynamics of an Entangled Security Dilemma: China's Changing Nuclear Posture. International Security 2023; 47 (4): 147–187. Doi: https://doi.org/10.1162/isec_a_00457.

Opposite: Hardtack I-Oak (J58-348-1)LA-UR-06-1068 (Los Alamos National Laboratory)

ISOTOPE ^{28}O UNIQUE PROPERTIES DEFY NUCLEAR THEORY

SUMMARY OF RESEARCH:

Researchers from 37 institutions, led by the Tokyo Institute of Technology, conducted a groundbreaking study on the rare isotope oxygen-28 (28O). They aimed to determine whether this isotope, which has a unique configuration of 20 neutrons and 8 protons, making it "doubly magic," could be bound by the strong nuclear force in spite of its high neutron count. Scientists at Japan's Radioactive Isotope Beam Factory observed the radioactive decay of 28O into 24O, finding that it was just barely unbound and unable to hold on to its neutrons long enough to form a stable nucleus. Complementing these experiments, advanced simulations conducted on Oak Ridge National Laboratory's Summit supercomputer confirmed with 98% probability that 28O is not a bound nucleus. This research delves into the behavior of rare isotopes, challenging traditional nuclear models, and paves the way for further exploration of the outer regions of the chart of nuclides, contributing to our understanding of exotic matter and the strong nuclear force.

WHY IT MATTERS TO CWMD:

The impact of this research extends to the field of nuclear physics, where it opens new avenues for understanding how nuclei behave under extreme conditions. Using cutting-edge computational techniques, like emulator algorithms, the study answers fundamental questions about the behavior of rare isotopes and demonstrates the potential of supercomputing in describing exotic matter from first principles. Furthermore, this research supports the work of the DOE's Facility for Rare Isotope Beams, offering insights that may lead to revisions or amendments to current nuclear models and expanding our knowledge of extreme nuclear structures where traditional models no longer apply.

REFERENCE:

Kondo, Y., Achouri, N.L., Falou, H.A. et al. First observation of 28O. Nature 620, 965–970 (2023). https://doi.org/10.1038/s41586-023-06352-6.

FIRST DEMONSTRATION OF A SELF-HEALING METAL

SUMMARY OF RESEARCH:

Researchers from Sandia National Laboratories and Texas A&M University have made a groundbreaking discovery regarding the self-healing ability of metals at the nanoscale. The study, published in the journal Nature, reveals that metals possess an intrinsic capacity to repair fatigue damage, a phenomenon previously believed to be impossible in metals. Fatigue damage caused by repeated stress or motion leads to microscopic cracks that can ultimately result in the failure of mechanical devices, costing billions of dollars annually. The research demonstrates that under certain conditions, metals can naturally heal these nanoscale fractures, challenging traditional materials science theories and opening new possibilities for materials engineering.

WHY IT MATTERS TO CWMD:

This discovery has profound implications for the resilience of the force facing the threat of WMD. It could potentially lead to the development of more durable and reliable materials, thus improving materiel survivability. Specifically, this discovery may lead to advances where the micro fractures and crystal defects from radiation damage can be spontaneously corrected. While there are still many unknowns and challenges to address before this self-healing property can be harnessed in practical applications, the finding represents a significant advancement in materials science and offers exciting opportunities for innovation in engineering and manufacturing.

REFERENCE:

Barr, C.M., Duong, T., Bufford, D.C. et al. Autonomous healing of fatigue cracks via cold welding. Nature 620, 552–556 (2023). https://doi.org/10.1038/s41586-023-06223-0.

NOVEL CORROSION PROCESS DISCOVERED IN MOLTEN SALT REACTORS

SUMMARY OF RESEARCH:

Researchers from multiple institutions, including Penn State, MIT, and Lawrence Berkeley National Laboratory, have made a significant discovery related to the corrosion of metals. They utilized advanced techniques such as 4D scanning transmission electron microscopy to study the corrosion process at a microscopic scale. What they found was a unique corrosion phenomenon they likened to "wormholes." In this process, molten salt selectively removes atoms from the metal during corrosion, creating one-dimensional "wormholes" along two-dimensional defects in the metal's structure, called grain boundaries. The researchers' findings have not only revealed a novel mechanism of corrosion but also suggested the potential for intentionally designing such structures for advanced materials, pointing to applications in various engineering systems.

WHY IT MATTERS TO CWMD:

This research has important implications for understanding and controlling corrosion, a common cause of material degradation in various industries. By gaining insights into how molten salt infiltrates specific metals and forms these one-dimensional pathways, researchers can work toward developing more resistant materials and predicting material failure more accurately. The ability to control or suppress this corrosion phenomenon is critical for the safety and longevity of advanced engineering systems, making this discovery a significant step forward in materials science and engineering.

REFERENCE:

Yang, Y., Zhou, W., Yin, S. et al. One dimensional wormhole corrosion in metals. Nat Commun 14, 988 (2023). https://doi.org/10.1038/s41467-023-36588-9.

CHEMICAL WARFARE SENSOR DESIGNED AND TESTED

SUMMARY OF RESEARCH:

Scientists at Rutgers laboratories have designed a synthetic protein that binds to the VX nerve agent, a chemical compound used in chemical warfare. The protein was created to generate a signal that could be coupled to a device, making it a biosensor for chemical weapons. The protein was tested against VX and underwent a dramatic shape change, burying VX in the cavity designed by the researchers. This shape change is the signal that could be coupled to a sensor device. The protein can detect VX at levels a thousand times more sensitive than current technologies without producing false positives.

WHY IT MATTERS TO CWMD:

This research opens another door for the development of biosensors, therapeutics, and diagnostics with applications in detecting and mitigating toxic nerve agents like VX. The designed protein could serve as a recognition element in various protein biosensor platforms, greatly enhancing sensitivity and specificity in detecting harmful substances. This innovation has the potential to improve safety and security measures against chemical warfare agents and other toxic compounds.

REFERENCE:

James J. McCann, Douglas H. Pike, Mia C. Brown, David T. Crouse, Vikas Nanda, Ronald L. Koder. Computational design of a sensitive, selective phase-changing sensor protein for the VX nerve agent. Science Advances, 2022; 8 (27) DOI: 10.1126/sciadv.abh3421.

ANALYZING BACTERIOPHAGES FOR ANTIBIOTIC TREATMENTS

SUMMARY OF RESEARCH:

This study delves into the world of bacteriophages (phages), viruses that infect bacteria. Phages employ various mechanisms to ultimately cause the destruction (lysis) of their bacterial hosts, a crucial step in their life cycle. While double-stranded DNA (dsDNA) phages rely on multiple proteins for host lysis, single-stranded RNA (ssRNA) phages and lytic single-stranded DNA (ssDNA) phages have a unique approach. They use a single gene, referred to as Sgl (single-gene lysis), to induce host lysis. These Sgls are responsible for triggering the autolysis of the host bacteria. The study focuses on understanding the molecular targets of these Sgls, especially those of ssRNA phages. It employs a high-throughput genetic screening method to identify host suppressors that interact with diverse Sgls. One key discovery is that the Sgl of the PP7 phage, which infects Pseudomonas aeruginosa, targets MurJ, a protein responsible for lipid II export, similar to the Sgl of coliphage M. Interestingly, these two Sgls, despite being unrelated and having opposite membrane topology predictions, both converge on the same target, highlighting a case of convergent evolution. The research extends these genetic screens to other uncharacterized Sgls, revealing a common set of multicopy suppressors, suggesting that these Sgls may share the same or similar mechanisms for inducing host lysis. The findings also provide insights into the genetic and molecular interactions between phages and their bacterial hosts, shedding light on the mechanisms underlying bacterial lysis and potential targets for future therapeutic interventions.

WHY IT MATTERS TO CWMD:

These findings advance our understanding of how phages induce bacterial host lysis, a critical process in phage biology. By identifying the molecular targets of diverse Sgls, the study uncovers important insights into the mechanisms these viruses employ to disrupt bacterial cells. The discovery that Sgls from different phages, such as PP7 and coliphage M, target the same protein, MurJ, highlights the concept of convergent evolution in phage biology, where unrelated Sgls evolve to exploit the same vulnerability in their bacterial hosts. This knowledge could pave the way for the development of novel therapeutic strategies, such as phage-based therapies or antibiotics that target specific host proteins involved in the phage life cycle. Additionally, the high-throughput genetic screening method used in this study provides a valuable tool for identifying suppressors of toxic genes, not limited to phages, which could have broad applications in understanding and manipulating gene functions in various biological contexts. Overall, this research contributes to our understanding of phage-host interactions and potential uses of phages in biotechnology and medicine.

REFERENCE:

Benjamin A. Adler, Karthik Chamakura, Heloise Carion, Jonathan Krog, Adam M. Deutschbauer, Ry Young, Vivek K. Mutalik, Adam P. Arkin. Multicopy suppressor screens reveal convergent evolution of single-gene lysis proteins. Nature Chemical Biology, 2023; DOI: 10.1038/s41589-023-01269-7.

WASTEWATER ANALYSIS OF PATHOGENS

SUMMARY OF RESEARCH:

This study focuses on wastewater-based surveillance, a method that gained prominence during the COVID-19 pandemic as an efficient means of monitoring infectious diseases in large populations. Ohio pioneered this approach with its Ohio Coronavirus Wastewater Monitoring Network (OCWMN), initially utilizing quantitative PCR (qPCR) to track COVID-19 prevalence at over 67 sites across the state. As the pandemic progressed, OCWMN evolved to include genome sequencing of SARS-CoV-2 to identify concerning variants. With the decline of the COVID-19 pandemic, the potential of wastewater surveillance extends to monitoring other infectious diseases and outbreaks, reducing the burden on healthcare systems. However, current surveillance methods mainly rely on qPCR for individual pathogens, which presents challenges for scaling to monitor multiple pathogens.

WHY IT MATTERS TO CWMD:

This research explores various genomic methods, both targeted and untargeted, to enhance wastewater-based biosurveillance. The objective is to find efficient procedures for detecting and tracking infectious diseases, known pathogens, and emerging variants. Over six weeks, RNA extracts from OCWMN sites were analyzed, with total RNA sequencing conducted using the Illumina NextSeq and MinION platforms to identify pathogens. MinION's long-read technology aims to simplify variant identification in mixed populations, a common challenge with short Illumina reads. Additionally, the study assesses the compatibility of a targeted hybridization approach with wastewater RNA samples. These research efforts aim to improve the scalability and effectiveness of wastewater-based surveillance, providing a valuable epidemiological tool for monitoring and mitigating infectious diseases in communities, beyond just COVID-19, in the post-pandemic world.

REFERENCE:

Spurbeck, R. R., Catlin, L. A., Mukherjee, C., Smith, A. K., & Minard-Smith, A. (2023). Analysis of metatranscriptomic methods to enable wastewater-based biosurveillance of all infectious diseases. Frontiers in Public Health, 11, 1145275.

BACTERIAL DETECTION OF LAND MINES

SUMMARY OF RESEARCH:

Researchers in Israel have achieved a significant breakthrough in landmine detection by utilizing genetically engineered E. coli bacteria. They've developed pellet-sized biosensors containing E. coli that are dispersed over target areas to detect the chemical signature of buried explosives, becoming luminescent upon detection. A drone is then employed to photograph the luminescent biosensors, revealing the precise location of landmines. The genetically engineered E. coli used in this biosensor project self-terminate shortly after deployment, ensuring no human or environmental risk. This innovative approach marks a transformative step in landmine detection, offering a 7-fold lower DNT detection threshold, a 45-fold increased signal intensity, and a 40 % shorter response time compared to previous methods for detecting landmines using bacteria.

WHY IT MATTERS TO CWMD:

Currently, landmines pose a significant threat worldwide, and their detection and removal are dangerous and costly endeavors. The E. coli-based biosensors, combined with AI and synthetic biology, provide a revolutionary solution that can accurately locate unexploded ordnance from a safe distance. This technology has the potential to dramatically enhance landmine clearance efforts, making them more efficient and less hazardous. Furthermore, the biosensors' adaptability to detect various other substances like explosives, environmental toxins, and hazardous chemicals suggests broader applications, promising safer and more sustainable solutions to other humanitarian and environmental challenges beyond landmine detection.

REFERENCE:

David, L., Shpigel, E., Levin, I., Moshe, S., Zimmerman, L., Dadon-Simanowitz, S., ... & Belkin, S. (2023). Performance upgrade of a microbial explosives' sensor strain by screening a high throughput saturation library of a transcriptional regulator. Computational and Structural Biotechnology Journal, 21, 4252-4260.

RICIN DETECTION USING HPLC-MS

SUMMARY OF RESEARCH:

In this study, researchers developed a groundbreaking method for accurately quantifying ricin, a highly toxic protein toxin, in complex matrices using ultra-high-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS). Traditional quantification methods faced challenges due to ricin's complex structure, specifically its interchain disulfide bonds, which hindered the production of suitable internal standards for precise measurements. The researchers overcame this hurdle by designing a novel protein standard absolute quantification (PSAQ) technique. They utilized recombinant mutant ricin (RMIS) as an internal standard, simplifying the process by creating a single-chain full-length sequence that linked the A-chain and B-chain. Extensive evaluations identified the most suitable protein IS, termed R1A, based on factors like digestion efficiency, LC-MS behavior, and antibody recognition function. By simultaneously detecting marker peptides from both chains, the team achieved accurate and absolute quantification of ricin in various complex samples, including milk, plasma, and river water.

WHY IT MATTERS TO CWMD:

This research marks a significant advancement in the field of toxin analysis and detection. By introducing a novel PSAQ technique utilizing recombinant mutant ricin as an internal standard, researchers have overcome major challenges associated with the quantification of ricin in complex samples. This innovative approach not only enhances the accuracy and precision of ricin measurements but also demonstrates the potential for addressing similar challenges in quantifying other complex proteins or toxins. The impact of this study extends beyond ricin analysis, serving as a pioneering model for developing advanced protein quantification technologies, which are crucial not only for scientific research but also for practical applications in fields such as bioterrorism prevention and environmental monitoring.

REFERENCE:

Long-Hui Liang, Yang-De Ma, et al. A protein standard absolute quantification strategy for enhanced absolute quantification of ricin in complex matrices using in vitro synthesized mutant holoprotein as internal standard by ultra-high-performance liquid chromatography-tandem mass spectrometry, Journal of Chromatography A, Volume 1708, 2023, 464373, ISSN 0021-9673, https://doi.org/10.1016/j.chroma.2023.464373.

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