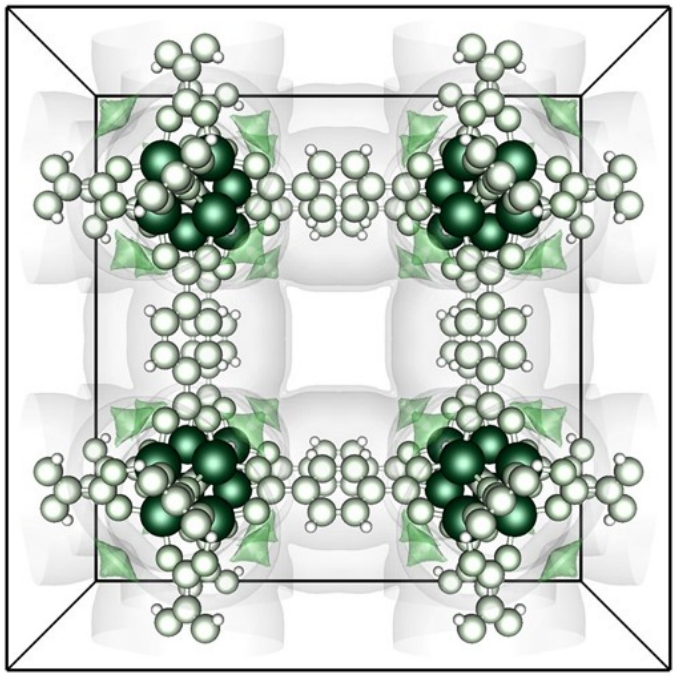
A Journal of Environmental Sciences Study Reveals That Metal-Organic Frameworks May Be Toxic

Researchers reveal how inhaled metal-organic frameworks disrupt blood cell formation in mice



Porous crystal structures of MIL-100(iron-based) and NH□-MIL-125 (titanium-based) were found to alter hematopoietic activity in the lungs, bone marrow and spleen. Structural composition and metal centers played a key role in determining the extent of immune disruption.

CHINA, June 24, 2025 /EINPresswire.com/ -- Metal-organic frameworks (MOFs) are popular nanomaterials with applications in drug delivery, catalysis and sensor-based technologies. However, in a new study researchers from China identified that pulmonary exposure to MOFs (MIL-100 and NH□-MIL-125) disrupts the production of blood and immune cells in mice. Flow cytometry studies revealed tissue-specific alterations in the bone marrow, spleen and lungs—posing potential biosafety risks. The study calls for stricter risk assessments to ensure safe deployment of MOFs.

Nanomaterials are reshaping the world of modern science with metal-organic frameworks (MOFs) as the next frontier in nanotechnology. These porous materials—made from metal ions and organic linkers—have rapidly emerged as promising candidates for drug delivery, gas storage, and environmental cleanup. MIL-100 and NH□-MIL-125 are two popular MOFs which have recently gained particular attention due to their structural stability, high surface area, and versatility. However, with great potential come significant risks of biosafety, especially when these materials are inhaled.

In this vein, a team of scientists along with Dr. Linlin Yao from Research Center for Eco-

Environmental Sciences, Chinese Academy of Sciences, China and Dr. Li Zeng from Research Center for Eco-environmental Engineering, Dongguan University of Technology, China conducted a comprehensive analysis to determine how pulmonary exposure to MIL-100 and NH□-MIL-125 affects hemopoiesis (the natural process of blood and immune cell formation). Their findings were made available online on August 10, 2024, and were published on October 01, 2025 in Volume 156 of the Journal of Environmental Sciences.

“MOFs have been in high demand for drug delivery lately, specifically for deep lung penetration, but their adverse effects have been understudied,” explains Dr. Yao. “Since lungs are of the important hemopoietic sites, we evaluated the effects of MOFs across key organs of hemopoiesis.”

To evaluate the effects of MOFs on hematopoiesis, the researchers first exposed adult male mice to MIL-100 or NH□-MIL-125 at doses relevant to real-world medical applications. They then examined changes in hematopoietic cells—the cells responsible for forming blood and immune cells—present in the bone marrow, lungs, and spleen. Samples were analyzed at two time points: one day and seven days after exposure, using advanced flow cytometry techniques.

The results were striking. On day 1, both MOFs suppressed the production of myeloid cells like monocytes and neutrophils in the bone marrow and lungs, while the production of lymphocytes in the spleen was also reduced. However, by day 7, a rebound effect was observed. Both lungs and bone marrow showed increased levels of granulocyte-monocyte progenitors and common myeloid progenitors—highlighting an inflammation-driven overproduction of immune cells. In contrast, the spleen continued to show suppressed production of myeloid cells, even at later time points.

Notably, MIL-100 has a greater effect on the hematopoietic cell populations compared to NH□-MIL-125. This was presumably due to differences in their metal centers: MIL-100 contains iron, which can generate reactive oxygen species and alter the bone marrow niche, whereas NH□-MIL-125 contains titanium, a biologically inert element.

“The iron in MIL-100 can potentially promote oxidative stress, disrupting the delicate balance of hematopoiesis,” explains Dr. Zeng.

Additionally, the team conducted histological analysis which revealed that MIL-100 caused acute inflammation through rapid buildup of immune cells in lung tissue on day one, which subsided by day seven. But at the same time, NH□-MIL-125 did not cause significant inflammation, suggesting the MOFs have different profiles of immunotoxicity. The study also revealed unique tissue-specific effects of the MOFs. For example, NH□-MIL-125 alone altered megakaryocyte progenitors in the lungs, which are responsible for platelet production. These effects highlight the complex interplay between the nanomaterials, their structure and the organs involved in the hematopoiesis.

The findings stand as an in vivo proof that while MOFs hold great promise in drug delivery, their potential to disrupt immune balance cannot be overlooked. Disrupted hematopoiesis can lead to a wide range of conditions including immunodeficiency, excessive inflammation and increased risks of developing cardiovascular diseases and cancer. Going forward, the researchers plan for mechanistic studies to decipher how different MOF structures influence signaling pathways related to immune and blood cell formation.

Overall, the study marks a key step toward understanding the potential adverse effects of MOFs while advocating for long-term safety assessments and refined material design strategies to minimize biological risks.

***

Reference
Title of original paper: Hematopoietic responses to metal-organic frameworks in adult mice following pulmonary exposure
Journal: Journal of Environmental Sciences
DOI: 10.1016/j.jes.2024.08.003

About the Chinese Academy of Sciences, Beijing, China
The Chinese Academy of Sciences (CAS) is China's premier scientific institution headquartered in Beijing, China, with a vast network of over 100 affiliated research institutes and centers spread across the country. Established in 1949, CAS plays a critical role in advancing science and technology across a wide range of disciplines, from physical and life sciences to engineering and environmental studies. It oversees more than 100 research institutes, universities, and innovation hubs across China. CAS is known for its contributions to national development, global scientific collaboration, and training of high-level scientific talent through its affiliated University of Chinese Academy of Sciences. Its work supports both fundamental research and applied technological breakthroughs.

Website: https://english.cas.cn/

About Dongguan University of Technology (DGUT)
Dongguan University of Technology (DGUT) is the sole model institution for advanced science and engineering collaboratively developed by both Guangdong Province and Dongguan City. As the first full-time public university established in Dongguan, DGUT has developed a distinctive academic structure centered on engineering, while also promoting balanced growth across disciplines such as management, humanities, science, economics, law, education, and more. The university comprises 20 colleges, offering 59 undergraduate programs and 11 postgraduate

programs.

Website: https://en.dgut.edu.cn/

About Dr. Linlin Yao from Chinese Academy of Sciences
Dr. Linlin Yao is a scientist at the State Key Laboratory of Environmental Chemistry and Ecotoxicology of Research Center for Eco Environmental Sciences, Chinese Academy of Sciences, China. Her research focuses on the analysis and toxicology of emerging organic pollutants and nanoparticles, including the development of analytical methods, investigation of immunotoxicity, and the study of intercellular communication.

About Dr.Li Zeng from Dongguan University of Technology
Dr. Li Zeng is working at Dongguan University of Technology. She has authored more than 29 peer-reviewed articles including analytical chemistry, environmental nanotoxicology, micro-/nano-plastics analysis. Her research focused on the nanotoxicology, including environmental transformation and exposure pathway of nanomaterial, cellular heterogeneity and molecular mechanisms. She has led and anticipated several National Natural Science Foundation of China projects and has been awarded with CAIA Science Award Special Prize as the third contributor.

Dr. Yue Liu
Journal of Environmental Sciences
+86 10-62920553
yueliu@rcees.ac.cn