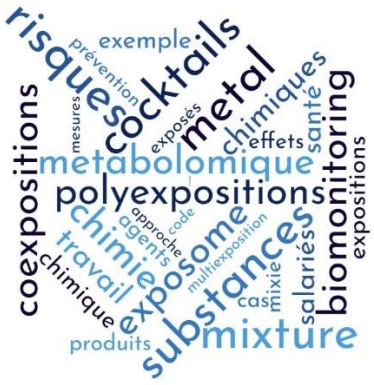

Bulletin de veille
Polyexpositions chimie-chimie
N°8 - mars 2025

Objectif : la polyexposition homogène chimie/chimie est un sujet de plus en plus préconisé pour étudier l'évaluation du risque professionnel et sa prévention. L'objectif est de connaitre les travaux récents qui sont publiés sur le sujet et identifier des moyens d'analyse, et d'interprétation de cette multiple exposition à plusieurs composés chimiques.

Ce bulletin a été réalisé à partir d'une surveillance de littérature récente sur les bases Web of Sciences et la base documentaire INRS-Biblio.

La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS. Les éléments issus de cette veille sont fournis sans garantie d'exhaustivité.

Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.

Actualités web sélectionnées

- 30 janvier 2025. Santé publique France. Surveillance des maladies respiratoires chroniques chez les travailleurs affiliés au régime général. Prévalences et secteurs d'activité et professions à risque à partir des données d'inclusion de la Cohorte Constances. Accès à l'article

- 25 février 2025. L'Usine nouvelle. L'exposition des salariés aux PFAS reste un angle mort de la santé au travail. « Polluants éternels », les PFAS sont présents dans de nombreux secteurs industriels où les salariés peuvent y être exposés dans des quantités importantes. Pourtant, les données manquent pour évaluer le nombre de travailleurs concernés et leur protection. Lien vers l'article
- Dans son rapport publié le 25 mars 2025, l'Académie des sciences donne son avis sur les PFAS et formule cinq recommandations, pour une étude approfondie sur « l'exposome chimique ». Lire le rapport

- Comment garantir des données précises et fiables dans le domaine de la biosurveillance humaine ? Le PARC organise une formation en présentiel sur l'assurance et le contrôle de la qualité, axée sur l'exactitude, la fiabilité et la comparabilité des résultats de mesure dans les études de biosurveillance humaine (HBM). Plus d'infos sur https://www.eu-parc.eu/news/building-capacities/how-can-you-ensure-accurate-and-reliable-data-human-biomonitoring-join-our

Sommaire

1. Généralités

Constantinescu, A. M., Karzi, V.E., Docea, A.O. Et Al.
Neurobehavioral effects of low dose exposure to chemical mixtures: a review.
Arch Toxicol 2025; Vol. Published 21 March, 2025

Neurological disorders have become the leading cause of disease and disability worldwide, with 80% of these conditions being recorded in low- and middle-income countries. Scientific evidence has increasingly associated these disorders with exposure to xenobiotics, such as pesticides, heavy metals and endocrine-disrupting chemicals (EDCs). Recent studies have focused on the consequences of exposure to chemical mixtures and their potential neurotoxic effects. As reported, such exposures can adversely affect cognitive and motor skills, particularly when they occur prenatally or during the early stages of development. Long-term exposure to mixtures of these substances has been strongly related to oxidative stress, inflammation and neurodegeneration.
This review aims to explore the neurobehavioral effects of low-dose xenobiotic combinations, stressing the potential long-term neurological damage from such exposure. The in vivo and epidemiological studies reviewed indicate that early-life exposure to chemical mixtures is linked to motor and cognitive disorders, increased anxiety prevalence and behavioral dysregulation. Mechanistic evidence suggests that these exposures may exacerbate oxidative stress, immune activation, and neuronal dysfunction, ultimately leading to neuroinflammation. Chemical interactions greatly affect neurotoxicity, often deviating from simple dose addition. Synergistic effects can arise at both low and high doses, while some studies also report antagonistic outcomes.
The specific impacts depend on the chemicals involved, their ratios, and the biological endpoints assessed. Since pollutants like heavy metals can persist in the environment due to their resistance to natural degradation processes, innovative strategies are necessary to mitigate the detrimental effects of exposure to chemical mixtures on human health and the environment.
https://doi.org/10.1007/s00204-025-04009-z

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Li, R. Q., Lin, X. Y., Lu, T. Y., Wang, J., Wang, Y., Xu, L.
Associations between exposure to multiple environmental chemicals and metabolic syndrome: A mixture analysis.
Hygiene and Environmental Health Advances décembre 2024; Vol. 12 ; 100112.

Exposure to environmental chemicals is prevalent. While previous studies reported associations between multiple chemical exposures and metabolic syndrome (MetS), they did not comprehensively account for correlations among exposures. We used machine learning methods including Boruta algorithm and least absolute shrinkage and selection operator (LASSO) regression, combined with weighted quartiles sum (WQS) regression to investigate the associations of phenols, polycyclic aromatic hydrocarbons (PAHs), metals, and phthalates with MetS and its components.
Data were drawn from the 2005-2012 National Health and Nutrition Examination Survey (NHANES). The mean (standard deviation (SD)) age of 2596 participants was 48.4 (17.9) years. After adjusting for age, sex, body mass index, race/ethnicity, marital status, education, poverty income ratio, physical activity, smoking, and alcohol, higher 2-Phenanthrene (2-PHE) and mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP) concentrations were associated with a higher odds of the MetS (odds ratio (OR) = 4.26, 95 % confidence interval (CI) 2.40-7.58 per ng/mL, and 3.24, 1.75-6.02 per ng/L, respectively). WQS index for environmental chemicals was positively associated with the MetS (OR = 1.31, 95 % CI 1.09-1.57). Moreover, we observed consistent and stronger positive associations with MetS (OR = 1.54, 95 % CI 1.04-2.30) in current smokers. Exposure to phenols, PAHs, metals, and phthalates was positively associated with an increase in metabolic syndrome and its components, which was more pronounced in current smokers.
https://doi.org/10.1016/j.heha.2024.100112

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Permana, K. M., Tannous, M., Mouaziz, H. Et Al.
Collecting perspectives on project prioritisation process in the EU co-funded multinational partnership for the assessment of risks from chemicals (PARC) through focus group discussion.
Environmental Sciences Europe 2025; Vol. 37 (2)

The European Partnership for the Assessment of Risks from Chemicals (PARC) is a 7-year multinational partnership aimed at consolidating and strengthening European Union's (EU) research and innovation capacity for chemical risk assessment (RA) to protect human health and the environment. It consists of nine work packages (WP) involving more than 200 participating organisations from 29 countries.
PARC is currently mapping the most relevant needs in the field of European chemical RA to steer PARC's future activities in the coming years. The present study aims to gather the perspectives of WP/Task/Project Leaders of PARC to understand their experience during the first prioritisation round of PARC activities and to identify potential points of improvement for future rounds.
Methods : Three online 90-min focus group discussion (FGD) sessions were conducted between the 3rd and 9th of May 2023. Each session was attended by 4-5 participants with at least one representative from each PARC WPs 4, 5 and 6 (n = 13). The sessions were recorded and transcribed, then analysed in NVivo 12 software using thematic analysis.
Results : Some important aspects for the prioritisation of activities that were mentioned include: (1) having a transparent prioritisation process even though each WP might need different prioritisation criteria, (2) balancing the fulfilment of short-term regulatory needs and anticipating long-term needs in chemical RA, (3) maintaining alignment and synergy between the WPs and with other relevant EU initiatives to avoid duplication and to ensure continuity of work and (4) making sure that PARC can effectively respond to requests from different PARC stakeholders.
Conclusions : The next round of PARC research activity steering process will provide an opportunity to implement the various improvements identified. PARC should utilise the advantage of having stakeholders from different backgrounds (e.g., risk assessors, policymakers, regulatory bodies, academia, etc.) within its consortium and its advising bodies to prioritise projects and activities that will support its overall objectives. These recommendations could also be of interest outside PARC in the context of prioritising research and innovation needs related to chemical RA.
https://doi.org/10.1186/s12302-024-01041-1

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Petit, P., Vuillerme, N.
Global research trends on the human exposome: a bibliometric analysis (2005-2024).
Environ Sci Pollut Res 2025 ; 32, p :7808–7833

Exposome represents one of the most pressing issues in the environmental science research field. However, a comprehensive summary of worldwide human exposome research is lacking. We aimed to explore the bibliometric characteristics of scientific publications on the human exposome. A bibliometric analysis of human exposome publications from 2005 to December 2024 was conducted using the Web of Science in accordance with PRISMA guidelines. Trends/hotspots were investigated with keyword frequency, co-occurrence, and thematic map.
Sex disparities in terms of publications and citations were examined. From 2005 to 2024, 931 publications were published in 363 journals and written by 4529 authors from 72 countries. The number of publications tripled during the last 5 years. Publications written by females (51% as first authors and 34% as last authors) were cited fewer times (13,674) than publications written by males (22,361). Human exposome studies mainly focused on air pollution, metabolomics, chemicals (e.g., per- and polyfluoroalkyl substances (PFAS), endocrine-disrupting chemicals, pesticides), early-life exposure, biomarkers, microbiome, omics, cancer, and reproductive disorders. Social and built environment factors, occupational exposure, multi-exposure, digital exposure (e.g., screen use), climate change, and late-life exposure received less attention.
Our results uncovered high-impact countries, institutions, journals, references, authors, and key human exposome research trends/hotspots. The use of digital exposome technologies (e.g., sensors, and wearables) and data science (e.g., artificial intelligence) has blossomed to overcome challenges and could

provide valuable knowledge toward precision prevention. Exposome risk scores represent a promising research avenue. © 2025. The Author(s).
https://doi.org/10.1007/s11356-025-36197-7

2. Biomarqueurs, biomonitoring

Jagani, R., Chovatiya, J., Patel, H., Andra, S. S.
Exploring the potential of MRM-IDA-EPI method in mass spectrometry for exposomic analysis: a commentary.
Archives of Toxicology ; January 2025.

Exposomics is a field that studies environmental exposures and their impact on human health. The MRM-IDA-EPI method, which combines targeted and untargeted mass spectrometry methods, is useful for identifying and quantifying biomarkers in various biological matrices. The method's accuracy and precision in forensic toxicological screening suggest potential applications for detecting low-level environmental exposures. It can help detect and understand environmental exposures, explain their metabolic processes, and assess their impact on human health more effectively.
https://doi.org/10.1007/s00204-025-03958-9

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He, R. J., Zhong, H. J., He, C., Li, H. L., Wang, Z. X., Zheng, J.*, et al.*
Individual and mixture effects of BTEX occupational exposure with hematologic and hepatic profiles in petrochemical workers and the metabolic mechanism.
Journal of Environmental Sciences 2025; Vol. 154 p 163-173.

Evidence on the association of occupational exposure to benzene, toluene, ethylbenzene, and xylene (BTEX) with hematologic and hepatic profiles were equivocal, and few studies have investigated overall effect of BTEX mixtures. Herein, significant higher concentrations ($p < 0.05$) of hippuric acid, 1,2-dihydroxybenzene, mandelic acid, trans, trans -muconic acid and phenylglyoxylic acid were found in petrochemical workers than the controls, in accordance with higher levels of hematologic and hepatic profiles found in petrochemical workers ($p < 0.05$).
Occupational exposure to individual BTEX was associated with elevated levels of white blood cell (WBC), lymphocyte (LYMPH), alanine aminotransferase (ALT), and gamma-glutamyl transferase (GGT). Further, the Weighted Quantile Sum Regression model and Bayesian Kernel Machine Regression model consistently identified a positive association between BTEX mixture exposure and WBC, LYMPH, and GGT. Xylene was the primary contributor to increased WBC, LYMPH, and GGT levels. Furthermore, BTEX exposure resulting in the increased inflammation indices were mainly related to perturbations of sphingolipid metabolism, biosynthesis of unsaturated fatty acids, and primary bile acid biosynthesis. Whereas metabolites mediated the correlation between BTEX exposure and liver function indices were related to the perturbations of biosynthesis of unsaturated fatty acids, arachidonic acid metabolism, sphingolipid metabolism, primary bile acid biosynthesis, etc.
Our findings revealed potential health risk of occupational exposure to BTEX and might help one to understand the link between BTEX exposure and hematologic and hepatic profiles. (c) 2025 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.
https://doi.org/10.1016/j.jes.2024.06.021

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Lee, J., Jang, H., Pearce, E. N., Shin, H.-M.
Exposome-wide association study of thyroid function using U.S. National Health and Nutrition Examination Survey data.
Environmental research 2025; Vol. 269 p 120884.

Previous epidemiologic studies examining thyroid function and chemical exposures have typically focused on a single or a limited number of chemical classes, often neglecting the effects of chemical mixtures. This study addressed this gap by exploring the associations between exposure to hundreds of chemicals and thyroid function using an exposome-wide association study (ExWAS) approach and National Health and Nutrition Examination Survey (NHANES) data.
We analyzed data from three NHANES cycles (2007-2008, 2009-2010, and 2011-2012), which include measures of thyroid function (free and total triiodothyronine [T3], free and total thyroxine [T4], thyroid-stimulating hormone [TSH]) and chemical biomarker concentrations from 9,082 participants. For adolescents (aged 12-19 years) and adults (aged ≥20 years), we employed multiple regression by accounting for survey weights to identify biomarkers associated with thyroid function test levels and used Bayesian group weighted quantile sum (BGWQS) regression to assess the effects of chemical mixtures on these measurements. After adjusting for multiple comparisons, we found in single exposure scenarios that 44 and 67 biomarkers were associated with at least one thyroid function measure in adolescents and adults, respectively (adjusted p-value <0.05).
In scenarios involving mixed chemical exposures, groups such as pesticides, sodium/iodide symporter (NIS) inhibitors, and metals were associated with alterations in thyroid hormones or TSH across both age groups. Volatile organic compounds were specifically linked to lower T4 levels in adolescents, whereas phenols and parabens were associated with lower TSH levels exclusively in adults. Although limited by the cross-sectional data, this study identified chemical biomarkers linked to thyroid function.
https://doi.org/10.1016/j.envres.2025.120884

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Carlin, D. J., Rider, C. V.
Combined Exposures and Mixtures Research: An Enduring NIEHS Priority.
Environmental Health Perspectives 2024; Vol. 132 (7)

BACKGROUND : The National Institute of Environmental Health Sciences (NIEHS) continues to prioritize research to better understand the health effects resulting from exposure to mixtures of chemical and nonchemical stressors. Mixtures research activities over the last decade were informed by expert input during the development and deliberations of the 2011 NIEHS Workshop "Advancing Research on Mixtures: New Perspectives and Approaches for Predicting Adverse Human Health Effects." NIEHS mixtures research efforts since then have focused on key themes including a) prioritizing mixtures for study, b) translating mixtures data from in vitro and in vivo studies, c) developing cross-disciplinary collaborations, d) informing component-based and whole-mixture assessment approaches, e) developing sufficient similarity methods to compare across complex mixtures, f) using systems-based approaches to evaluate mixtures, and g) focusing on management and integration of mixtures-related data.
OBJECTIVES : We aimed to describe NIEHS driven research on mixtures and combined exposures over the last decade and present areas for future attention.
RESULTS : Intramural and extramural mixtures research projects have incorporated a diverse array of chemicals (e.g., polycyclic aromatic hydrocarbons, botanicals, personal care products, wildfire emissions) and nonchemical stressors (e.g., socioeconomic factors, social adversity) and have focused on many diseases (e.g., breast cancer, atherosclerosis, immune disruption). We have made significant progress in certain areas, such as developing statistical methods for evaluating multiple chemical associations in epidemiology and building translational mixtures projects that include both in vitro and in vivo models.
DISCUSSION : Moving forward, additional work is needed to improve mixtures data integration, elucidate interactions between chemical and nonchemical stressors, and resolve the geospatial and temporal nature of mixture exposures. Continued mixtures research will be critical to informing cumulative impact assessments and addressing complex challenges, such as environmental justice and climate change.

https://doi.org/10.1289/ehp14340

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Shilnikova, N., Momoli, F., Karyakina, N., Krewski, D.
Review of non-invasive biomarkers as a tool for exposure characterization in human health risk assessments.
Journal of Toxicology and Environmental Health-Part B-Critical Reviews 2025; Vol. 28 (2) ,p 122-150.

Blood and urine are historically the most frequent matrices used for measuring chemical levels in human biomonitoring studies. As biomonitoring programs are refreshed, consideration of specific priority substances and specific population targets provide opportunities for inclusion of alternative non- or minimally invasive matrices.
This review describes methods used in health risk assessment to characterize exposure and risk based upon biomarkers from noninvasive matrices other than urine or blood, including human milk, hair, fingernails, toenails, exhaled breath, deciduous teeth, sweat, semen, meconium, and feces. Illustrative examples of these methods relevant to chemical management are provided. This review suggests that, although these alternative noninvasive biomarkers are not frequently used in human health risk assessment at present, these biomarkers may prove useful in (1) characterizing exposure and health risk in vulnerable populations, (2) cumulative risk assessments, and (3) community-based risk assessments, depending upon the substance of concern.
To incorporate alternative noninvasive biomarkers into human health risk assessments with confidence, more research is needed to improve our knowledge of the relationships between external dose, internal dose, and biologic consequent effects in matrices other than blood and urine.
https://doi.org/10.1080/10937404.2024.2428206

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Bargues-Carot, A., Prado-Rico, J., Kawasawa, Y. I., Cai, J., Yanosky, J. D., Zenitsky, G.*, et al.*
MicroRNA Expression in Asymptomatic Welders: Implications for Biomarker Discovery for Environmentally-Linked Neurodegenerative Disorders.
medRxiv 2025.02.10.25322027

Chronic occupational exposure to metals in welding fumes has been implicated in the etiology of neurodegenerative diseases (NDDs), including Parkinson's disease (PD) and Alzheimer's disease (AD). Changes in microRNA (miRNA) expression have been associated with various neurodegenerative conditions. Circulating miRNAs, in particular, have emerged as promising, minimally invasive biomarkers for diagnosing and monitoring disease progression.
This study was designed to characterize the expression of miRNAs in neuronally-enriched serum extracellular vesicles (EVs) among welders and non-welders to explore their potential link to metal concentrations and welding exposure measures and their potential as early diagnostic biomarkers for neurodegeneration.
Serum samples from 39 welders and 27 healthy individuals were collected, and EV-enclosed miRNAs were extracted and analyzed. Also, whole blood metal concentrations and welding exposure measurements were obtained. Fifty miRNAs were found to be dysregulated in welders vs. non-welders, of which three (miR-16-5p, miR-93-5p, miR-486-5p) showing reduced expression and two (miR-4281 and miR-4417) exhibiting positive correlations with blood metal concentrations as well as with long- and short-term welding exposure measures.
The dysregulation of these miRNAs suggests that exposure to metals could disrupt important biological processes, possibly contributing to an elevated risk of NDDs.
These findings highlight the need for further research to validate the causal relationship between exposure to metals in welding fumes, the dysregulation of circulating miRNAs, and their role in neurodegenerative disease development, with implications for miRNA-based biomarkers in early disease detection and prevention.
https://doi.org/10.1101/2025.02.10.25322027

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Hopf, N. B., Bessems, J., Santonen, T., Viegas, S., Casteleyn, L., Poddalgoda, D., *et al.*
Introducing the OECD guidance document on occupational biomonitoring: A harmonized methodology for deriving occupational biomonitoring levels (OBL).
Toxicology Letters 2025; Vol. 403 p 132-143.

Derivation of occupational biomonitoring levels (OBLs) is needed to effectively utilize biomonitoring for assessing exposures to chemical substances, and consequently, implement risk reduction measures to reduce health risks among workers. OBLs are the appropriate option for chemical substances that can be absorbed through the skin.
This methodology for derivation of OBLs has been developed in collaboration with scientific and regulatory experts from more than 40 institutes in 15 countries within the Organization for Economic Cooperation and Development (OECD) framework.
This manuscript provides a summary of the guidance on derivation of OBLs destined for scientists, risk assessors, and regulators who are tasked with establishing OBLs for regulatory purposes and implementing occupational biomonitoring programs. The derivation methodology follows a tiered approach based on the strength of evidence and quality of the data that we have labeled level of confidence. The tiered approach serves as a practical framework in occupational health risk assessment and management.
We distinguish between four OBL levels depending on the strength of scientific evidence and confidence level: health-based derivation of OBL based on robust epidemiological data showing causal exposure-health effect relationship and Provisional OBL (POBL) based on robust toxicological animal data showing dose- response relationship as well as two assessment values which are not health based: reference levels in the general population (Reference OBL or (ROBL)), and Technical achievable OBL or (TOBL). Four case studies illustrating the derivation methods for OBLs and POBLs are also provided. Using this state-of-the-art approach (OECD guidance document no. 370) will lead to a harmonized derivation of OBLs and subsequently to evidence-based risk management measures.
https://doi.org/10.1016/j.toxlet.2024.12.006

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Bo Peng, M. L., Tong Zhu, and Mingliang Fang.
Optimizing Human Exposome Biomonitoring: A Machine Learning Approach to Predict Optimal Biofluid Matrices.
Environmental Science & Technology Letters 2025; Online March 23, 2025

Biomarker identification is crucial for exposomic studies, yet few have been established relative to the vast number of chemicals human encounter. While biomarkers can be detected in blood or urine, the optimal biological matrix for each chemical remains unclear.
We curated data on biomarker identification in urine or blood for 526 chemicals from 4797 biomonitoring entities, sourced from 89 distinct cohorts across 43 countries, and developed a machine learning model named Biomarker Matrix Identifier (BMI) to predict the most suitable biological fluid for biomarker identification. Our model achieves over 94% accuracy using circular fingerprints as the input. Applying this method to the Human Exposomic Metabolome Database (HExPMetDB) containing over 20,000 chemicals revealed that approximately 67% of compounds are predicted to be more effectively monitored using urine as the optimal biomonitoring matrix.
This predictive model enhances the accuracy of the exposure assessment in human exposomic analysis, facilitating more efficient biomarker identification strategies.
In sum, we have established an effective prediction model in facilitating the prediction of whether the identified chemicals in the biological fluids can represent exposure for human exposomic analysis.
https://doi.org/10.1021/acs.estlett.5c00039

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3. Approches métabolomiques

Ciccarelli, D., Samanipour, S., Rapp-Wright, H., Bieber, S., Letzel, T., Obrien, J. W.*, et al.*
Bridging knowledge gaps in human chemical exposure via drinking water with non-target screening.
Critical Reviews in Environmental Science and Technology 2025; Vol. 55 (3) p 190-214.

Fundamental knowledge gaps still exist in the exposome, especially regarding analytical space coverage, mapping and prioritization of a very large number of diverse chemical structures. This review focuses on the contributions of suspect and non-target screening (NTS) to contaminants characterization and toxicity assessment in drinking water.
A comprehensive review of publications from 2013-2024 revealed only 172 substances identified with certainty using NTS and in 17 countries. The analytical approaches, their complementarity, effectiveness and use with compound identification frameworks are discussed. The use of 'intelligent' tools (including machine learning) to aid with substance identification, prioritization and toxicity assessment is emerging. Strategies for integration of NTS in epidemiology are also considered, including re-use of existing data. NTS holds great potential for chemical exposure assessment from drinking water and its contribution to the exposome.
https://doi.org/10.1080/10643389.2024.2396690

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Ge, Y., Nash, M. S., Farraj, A. K.
Metabolomic profiling reveals systemic metabolic disruptions induced by combined exposure to particulate matter and ozone.
Current Research in Toxicology 2025; Vol. 8, 100216.

Air pollution exposure, especially particulate matter (PM) and ozone (O3), poses significant health risks, but the systemic metabolic consequences of combined exposures to PM and O3, remain poorly understood. This study investigated systemic metabolic changes in male spontaneously hypertensive (SH) rats following inhalation exposure to concentrated ambient particles (CAPs) (PM2.5, 150 µg/m3), ozone (O3) (0.2 ppm), and their combination.
Rats were exposed for 4 h, and serum samples were collected 1-hour post-exposure. Using targeted metabolomics, we identified significant alterations in metabolites involved in lipid metabolism (phosphatidylcholines), energy metabolism (acylcarnitine C3), and oxidative stress (glutamine). Notably, the combination exposure induced distinct metabolic changes, including increased acylcarnitine C3 levels, suggesting heightened mitochondrial dysfunction. Principal component analysis revealed overlapping profiles between CAPs and controls, indicating a subtler impact of CAPs compared to ozone or combined exposure. These systemic metabolic alterations are aligned with our previously published proteomics findings in cardiac tissues from the same rats, which showed elevated inflammatory markers (e.g., IL-6, TNF-α) and mitochondrial dysfunction.
In conclusion, this study provides new insights into the systemic metabolic effects of air pollutant exposure, identifies novel metabolic targets of pollutant-induced toxicity, highlights the complex interactions resulting from combined exposure to multiple pollutants, and underscores the importance of assessing the combined effects of multiple pollutants in air pollution risk assessments.
https://doi.org/10.1016/j.crtox.2025.100216

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Guan, P., Wang, Y., Chen, T., Yang, J., Wang, X., Xu, G., Liu, X.
Novel Method for Simultaneously Untargeted Metabolome and Targeted Exposome Analysis in One Injection.
Analytical chemistry 2025; Vol. 97 (7) p 3996-4004.

Serum endogenous metabolites and coexisting exogenous compounds are closely related to human health. Metabolomics often uses high-resolution mass spectrometry (HRMS), but current exposomics studies typically rely on triple quadrupole tandem mass spectrometry due to lower concentrations in the body. As a result, metabolome-exposome-wide association studies (mEWAS) require a combination of untargeted metabolomics and several targeted exposomics methods to measure more exposures, leading to increased time and sample consumption.
In this study, a novel method was proposed by leveraging the advantages of recently introduced Zeno MRMHR technology; it allows for the simultaneous acquisition of the metabolome in HRMS and the exposome in multiple reaction monitoring (MRM) modes in one injection. The signal responses for exogenous compounds in MRM were comparable to those of metabolites in HRMS. This method was rigorously validated, and all exogenous standards had relative standard deviations (RSDs) below 20% for intraday and interday repeatability. Over 90% of metabolic features exhibited RSDs below 20% in these assessments. The method also had a broad quantification range, with lower limits of quantification (LLOQ) from 0.1 to 25 ng/mL and higher limits of quantification (HLOQ) from 2.5 to 1000 ng/mL.
This approach was demonstratively applied to a type 2 diabetes mellitus cohort to identify serum risk factors and study the metabolome-exposome association. To our knowledge, this study is the first implementation of a unified method for the simultaneous analysis of endogenous metabolites in the untargeted mode and 210 exogenous compounds in the targeted mode in one injection, offering a novel tool for mEWAS research.
https://doi.org/10.1021/acs.analchem.4c05565

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Hou M, T. S., Zhang F, Fu S, Ding H Et Al.
Chemical exposure in females of childbearing age associated with sex hormones: Evidence from an untargeted exposomic approach.
Environment International 2025; Vol. 197 p 109362.

Exposure to organic chemicals can cause reproductive hormones disturbance in women. However, there is very limited evidence regarding real-world chemical exposures in reproductive-aged women and their joint effects on sex hormone levels. Here, we applied non-targeted screening workflow based on High-Performance Liquid Chromatography-High-Resolution Mass Spectrometry to investigate the serum chemical exposome of 156 women of childbearing age from Jinan, China.
A total of 185 exogenous chemicals from 19 categories were identified in at least 80% of serum samples with confidence levels 1–3, 84 of which have never been reported in humans, and 9 of those showed active effects on multiple biological targets in ToxCast program. A combination of grouped weighted quantile sum regression (GWQS), weighted quantile sum regression (WQS), quantile g calculation (q g-comp), and Bayesian kernel machine regression (BKMR) models indicated significant associations of chemical mixture exposure with progesterone (P4), testosterone (T), and luteinizing hormone (LH)/follicle-stimulating hormone (FSH) ratios, and 7, 4, and 8 priority contributors were identified, respectively, such as fipronil sulfone for P4, dicyclohexyl phthalate for T, and 3-hydroxybenzyl alcohol for LH/FSH. Three chemicals closely related to androgen synthesis and metabolism were proposed. Restricted cubic spline curves showed that 10 of the 28 priority compound-hormone pairs displayed significant non-monotonic exposure–response relationships.
This study provides more information on the chemical exposome in Chinese women of childbearing age and has important implications for understanding the effect of chemical co-exposure on sex hormone homeostasis in women.
https://doi.org/10.1016/j.envint.2025.109362

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Kozlowska, L., Viegas, S., Scheepers, P. T. J., Duca, R. C., Godderis, L., Martins, C.*, et al.*
HBM4EU E-waste study - An untargeted metabolomics approach to characterize metabolic changes during E-waste recycling.
Environment International 2025; Vol. 196, 109281

E-waste contains hazardous chemicals that may be a direct health risk for workers involved in recycling. We conducted an untargeted metabolomics analysis of urine samples collected from male e-waste processing workers to explore metabolic changes associated with chemical exposures in e-waste recycling in Belgium, Finland, Latvia, Luxembourg, the Netherlands, Poland, and Portugal.
Questionnaire data and urine samples were obtained from workers involved in the processing of e-waste (sorting, dismantling, shredding, pre-processing, metal, and non-metal processing), as well as from controls with no known occupational exposure. Pre- and post-shift urine samples were collected and analysed using ultrahigh-performance liquid chromatography-mass spectrometry (UPLC-MS). A total of 32 endogenous urinary metabolites were annotated with a Variable Importance in Projection (VIP) above 2, indicating that e-waste recycling is mainly associated with changes in steroid hormone and neurotransmitter metabolism, energy metabolism, bile acid biosynthesis, and inflammation.
The highest VIP was observed for dopamine-o-quinone, which is linked to Parkinson's disease. These and other changes in metabolism in workers employed in the processing of e-waste need further verification in targeted studies.
https://doi.org/10.1016/j.envint.2025.109281

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Lu, P., He, R., Wu, Y., Wu, B., Li, H., He, C.*, et al.*
Urinary metabolic alterations associated with occupational exposure to metals and polycyclic aromatic hydrocarbons based on non-target metabolomics.
Journal of Hazardous Materials 2025; Vol. 487 ; 137158.

Long-term occupational exposure to metals and organics have been reported to be under great health risks. However, limited data are available on the molecular mechanism between combined exposure to metals and polycyclic aromatic hydrocarbons (PAHs) and harmful health effects.
In present work, non-target metabolomics study was conducted based on urine samples from nonferrous metal smelting workers (n = 207), surrounding residents (n = 180), and the control residents (n = 187) by using ultra-high-performance liquid chromatography coupled with quadrupole time-of-flight mass spectrometry (UHPLC-QTOF-MS). Differential and correlation analyses among metabolic features indicate that total 22 differential metabolites in smelting workers were associated ($p < 0.05$) with metal and PAH exposure. Particularly, amino acid metabolism was strongly disturbed, and other metabolic pathways, including steroid hormone biosynthesis, citrate cycle, and pantothenate and coenzyme A (CoA) biosynthesis were also perturbed. Among them, steroid hormone biosynthesis was more affected by PAH exposure than metals, especially for hydroxyphenanthrene. These altered pathways were closely associated with oxidative stress, inflammation, and energy metabolism disorder.
Additionally, our results indicate that endogenous metabolism in surrounding residents were also affected by nonferrous metal smelting activities to some extent. Our work provides valuable insights into molecular mechanisms of adverse health effects probably induced by combined exposure to metals and PAHs.
https://doi.org/10.1016/j.jhazmat.2025.137158

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Shi, Y., Li, K., Ding, R., Li, X., Cheng, Z., Liu, J.*, et al.*
Untargeted metabolomics and machine learning unveil the exposome and metabolism linked with the risk of early pregnancy loss.
Journal of Hazardous Materials 2025; Vol. 488, 137362.

Early pregnancy loss (EPL) may result from exposure to emerging contaminants (ECs), although the underlying mechanisms remain poorly understood. This case-control study measured over 2000 serum

features, including 37 ECs, 6 biochemicals, and 2057 endogenous metabolites, in serum samples collected from 48 EPL patients and healthy pregnant women. The median total concentration of targeted EC in the EPL group (65.9 ng/mL) was significantly higher than in controls (43.0 ng/mL; $p < 0.05$). Four machine learning algorithms were employed to identify key molecular features and develop EPL risk prediction models. A random forest model based on chemical data achieved a predictive accuracy of 95 %, suggesting a potential association between EPL and chemical exposure, with phthalic acid esters identified as significant contributors. Ninety-five potential metabolite biomarkers were selected, which were predominantly enriched in pathways related to spermidine and spermine biosynthesis, ubiquinone biosynthesis, and pantothenate and coenzyme A biosynthesis. C17-sphinganine was identified as a leading biomarker with an area under the curve of 0.93. Furthermore, exposure to bis(2-ethylhexyl)phthalate was linked to an increased risk of EPL by disrupting lipid metabolism. These findings indicate that combining untargeted metabolomics with machine learning approaches offers novel insights into the mechanisms of EPL related to EC exposure.
https://doi.org/10.1016/j.jhazmat.2025.137362

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Stanciu, A. R., Gillespie, C., Britz-Mckibbin, P.
Environmental Exposures and Health Risks: A Metabolomics Perspective on Exposomics Research.
Annual review of analytical chemistry (Palo Alto, Calif.) 2025; Vol 18, online on February 10.

Exposomics refers to the comprehensive analysis of environmental exposures over the lifespan and assessment of their biological effects on human health. This new frontier in environmental research promises new insights for assessment of the hazards of complex chemical exposures as compared to targeted biomonitoring of a limited panel of known toxicant(s).
Metabolomics plays a pivotal role in expanding exposomic initiatives that require orthogonal separation methods coupled to high-resolution mass spectrometry while using minimally invasive specimens from prospective cohort studies that can capture early life exposures.
However, several grand analytical challenges remain, including high-throughput metabolomic data workflows that are scalable to large populations, the identification of unknown contaminants and their contact sources, and elucidating the impact of multiple co-exposures at critical stages of development. In this review, we outline new advances in metabolomic technologies for exposomics research over the past five years that are urgently needed to guide regulatory policies via better exposure mitigation and strategies to improve metabolic resilience.
https://doi.org/10.1146/annurev-anchem-071524-125307

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Stanfield, Z., Favela, K., Yau, A., Menn, C., Edrisi, H., Phillips, K. A.*, et al.*
Developing Chemical Signatures for Categories of Household Consumer Products Using Suspect Screening Analysis.
Environmental Science & Technology 2025; Vol. 59 (2) p 1354-1366.

Consumer products are a major source of chemicals that may pose a health risk. It is important to understand what chemicals are in these products to evaluate risk and assess new products for uncommon ingredients. Suspect screening analysis (SSA) using two-dimensional gas chromatography-high-resolution-time-of-flight/mass spectrometry (GCxGC-HR-TOF/MS) was applied to 92 consumer products from 5 categories. 485 probable chemical structures were tentatively identified using the NIST 2017 spectral library across all products (109 confirmed). Chemicals were characterized by functional use and structural class. Fabric upholsteries contained the most chemicals (239) identifiable by GCxGC-HR-TOF/MS and silicone kitchen tools the least (64). Use of duplicate samples and repeat purchases of products allowed for a within-product category similarity assessment, which showed highest variability in baby soap and lowest in cotton clothing. Chemical ingredient signatures (including reported sample abundance ranges) for each product type were obtained by identifying chemicals occurring in >= 80% of product samples. These signatures provide a baseline set of chemical ingredients (that is, representative mixtures) across common consumer

product types. The chemical signatures will help in evaluating new and existing products. Separating constituent chemicals into typical and atypical might inform exposure assessment, in vitro bioactivity screening, and ultimately the risk related to using such products.
https://doi.org/10.1021/acs.est.4c09853

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Wang, Y., Zhuang, Z., He, G., Zalán, Z., Shi, H., Du, M.*, et al.*
A preliminary study of combined toxicity and underlying mechanisms of imidacloprid and cadmium coexposure using a multiomics integration approach.
Toxicology 2025; Vol. 511 ; 154063.

Imidacloprid (IMI) and cadmium (Cd) have been shown to be harmful to mammals separately, but their combined toxicity to mammals remains largely unknown. In this study, biochemical analysis (oxidative stress and serum indicators of liver and kidney function), pathological sections and multiomics (metabolomics and transcriptomics) methods were used to investigate the changes and mechanisms of liver and kidney in mice coexposed to IMI and Cd.
Biochemical analysis and pathological section results showed that oxidative stress, organ function, and cell damage were aggravated after the combination of the two methods. Omics results revealed the following mechanism: When mouse liver and kidney cells were threatened by the external environment, mitochondrial DNA was inhibited, which leads to changes in energy metabolism. In this process, lipid metabolism and amino acid metabolism were disordered, resulting in the inhibition of substances related to lipid metabolism and amino acid metabolism that protect the body from oxidative damage, and then showed more serious liver and kidney oxidative stress and liver and kidney function and cell damage.
This research offers novel insights for the assessment of the safety profile associated with the concurrent exposure of the two chemicals in mammalian species.
https://doi.org/10.1016/j.tox.2025.154063

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Yu, M., Li, Q., Dolios, G., Tu, P. J., Teitelbaum, S., Chen, J., Petrick, L.
Active Molecular Network Discovery Links Lifestyle Variables to Breast Cancer in the Long Island Breast Cancer Study Project.
Environment & Health 2024; Vol. 2 (6) p 401-410.

A healthy lifestyle has been associated with decreased risk of developing breast cancer. Using untargeted metabolomics profiling, which provides unbiased information regarding lifestyle choices such as diet and exercise, we aim to identify the molecular mechanisms connecting lifestyle and breast cancer through network analysis. A total of 100 postmenopausal women, 50 with breast cancer and 50 cancer-free controls, were selected from the Long Island Breast Cancer Study Project (LIBCSP). We measured untargeted plasma metabolomics using liquid chromatography-high-resolution mass spectrometry (LC-HRMS). Using the "enet" package, we retained highly correlated metabolites representing active molecular network (AMN) clusters for analysis. LASSO was used to examine associations between cancer status and AMN metabolites and covariates such as BMI, age, and reproductive factors. LASSO was then repeated to examine associations between AMN metabolites and 10 lifestyle-related variables including smoking, physical activity, alcohol consumption, meat consumption, fruit and vegetable consumption, and supplemental vitamin use. Results were displayed as a network to uncover biological pathways linking lifestyle factors to breast cancer status.
After filtering, 851 "active" metabolites out of 1797 metabolomics were retained in 197 correlation AMN clusters. Using LASSO, breast cancer status was associated with 71 "active" metabolites. Several of these metabolites were associated with lifestyle variables including meat consumption, alcohol consumption, and supplemental beta-carotene, B12, and folate use. Those metabolites could potentially serve as molecular-level biological intermediaries connecting healthy lifestyle factors to breast cancer, even though direct associations between breast cancer and the investigated lifestyles at the phenotype level are not evident. In particular, DiHODE, a metabolite linked with inflammation, was associated with breast cancer status and

connected to beta-carotene supplement usage through an AMN.
We found several plasma metabolites associated with lifestyle factors and breast cancer status. Future studies investigating the mechanistic role of inflammation in linking supplement usage to breast cancer status are warranted.
https://doi.org/10.1021/envhealth.3c00218

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4. Méthodes, modèles d'analyses

Bellavia, A.
Statistical Methods for Environmental Mixtures: A Primer in Environmental Epidemiology.
Springer Nature Switzerland; 2025. 99 pages.

This book provides a comprehensive introduction to statistical approaches for the assessment of complex environmental exposures, such as pollutants and chemical mixtures, within the exposome framework. Environmental mixtures are defined as groups of 3 or more chemical/pollutants, simultaneously present in nature, consumer products, or in the human body.
Assessing the health effects of environmental mixtures poses several methodological challenges due to the high levels of correlation that are often present between environmental chemicals, and by the need of incorporating flexible non-additive and non-linear effects that can capture and describe the complex mechanisms by which environmental exposure contribute to diseases.
Several statistical approaches are proposed and discussed, including the application of regression-based approaches (e.g. penalized regression such as LASSO and elastic net, or Bayesian variable selection) for environmental exposures, and novel methods (e.g. weighted quantile sum regression, or Bayesian Kernel Machine Regression) that account for specific complexities of environmental exposures. More recent efforts included are the application of machine learning approaches (e.g. gradient boosting) for environmental data.
https://books.google.fr/books?id=6FhCEQAAQBAJ

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Castro-Alves, V., Nguyen, A. H., Barbosa, J. M. G., Oresic, M., Hyotylainen, T.
Liquid and gas-chromatography-mass spectrometry methods for exposome analysis.
Journal of chromatography. A 2025; Vol. 1744, 465728.

Mass spectrometry-based methods have become fundamental to exposome research, providing the capability to explore a broad spectrum of chemical exposures. Liquid and gas chromatography coupled with low/high-resolution mass spectrometry (MS) are among the most frequently employed platforms due to their sensitivity and accuracy. However, these approaches present challenges, such as the inherent complexity of MS data and the expertise of biologists, chemists, clinicians, and data analysts to integrate and interpret MS data with other datasets effectively. The "omics" era advances rapidly, driven by developments of AI-based algorithms and an increase in accessible data; nevertheless, further efforts are necessary to ensure that exposomics outputs are comparable and reproducible, thus enhancing research findings.
This review outlines the principles of MS-based methods for the exposome analytical pipeline, from sample collection to data analysis. We summarize and review both standard and cutting-edge strategies in exposome research, covering sample preparation, focusing on MS-based platforms, data acquisition strategies, and data annotation. The ultimate goal of this review is to highlight applications that enable the simultaneous analysis of endogenous metabolites and xenobiotics, which can help enhance our understanding of the impact of human exposure on health and disease and support personalized

healthcare.

https://doi.org/10.1016/j.chroma.2025.465728

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Fresnais, L., Perin, O., Riu, A., Grall, R., Ott, A., Fromenty, B.*, et al.*
A strategy to detect metabolic changes induced by exposure to chemicals from large sets of condition-specific metabolic models computed with enumeration techniques.
BMC Bioinformatics 2024; Vol. 25 ; 234

Background: The growing abundance of in vitro omics data, coupled with the necessity to reduce animal testing in the safety assessment of chemical compounds and even eliminate it in the evaluation of cosmetics, highlights the need for adequate computational methodologies. Data from omics technologies allow the exploration of a wide range of biological processes, therefore providing a better understanding of mechanisms of action (MoA) related to chemical exposure in biological systems. However, the analysis of these large datasets remains difficult due to the complexity of modulations spanning multiple biological processes.
Results: To address this, we propose a strategy to reduce information overload by computing, based on transcriptomics data, a comprehensive metabolic sub-network reflecting the metabolic impact of a chemical. The proposed strategy integrates transcriptomic data to a genome scale metabolic network through enumeration of condition-specific metabolic models hence translating transcriptomics data into reaction activity probabilities. Based on these results, a graph algorithm is applied to retrieve user readable sub-networks reflecting the possible metabolic MoA (mMoA) of chemicals. This strategy has been implemented as a three-step workflow. The first step consists in building cell condition-specific models reflecting the metabolic impact of each exposure condition while taking into account the diversity of possible optimal solutions with a partial enumeration algorithm.
In a second step, we address the challenge of analyzing thousands of enumerated condition-specific networks by computing differentially activated reactions (DARs) between the two sets of enumerated possible condition-specific models.
Finally, in the third step, DARs are grouped into clusters of functionally interconnected metabolic reactions, representing possible mMoA, using the distance-based clustering and subnetwork extraction method. The first part of the workflow was exemplified on eight molecules selected for their known human hepatotoxic outcomes associated with specific MoAs well described in the literature and for which we retrieved primary human hepatocytes transcriptomic data in Open TG-GATEs.
Then, we further applied this strategy to more precisely model and visualize associated mMoA for two of these eight molecules (amiodarone and valproic acid). The approach proved to go beyond gene-based analysis by identifying mMoA when few genes are significantly differentially expressed (2 differentially expressed genes (DEGs) for amiodarone), bringing additional information from the network topology, or when very large number of genes were differentially expressed (5709 DEGs for valproic acid). In both cases, the results of our strategy well fitted evidence from the literature regarding known MoA. Beyond these confirmations, the workflow highlighted potential other unexplored mMoA.
Conclusion: The proposed strategy allows toxicology experts to decipher which part of cellular metabolism is expected to be affected by the exposition to a given chemical. The approach originality resides in the combination of different metabolic modelling approaches (constraint based and graph modelling). The application to two model molecules shows the strong potential of the approach for interpretation and visual mining of complex omics in vitro data. The presented strategy is freely available as a python module (https://pypi.org/project/manamodeller/) and jupyter notebooks (https://github.com/LouisonF/MANA).
https://doi.org/10.1186/s12859-024-05845-z

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Hamid, N., Yue, Q., Wang, J., Junaid, M.
Challenges and Prospects in the Application of Experimental, Analytical, and Predictive Models in Combined Toxicity Assessment.
In: Toxicological Assessment of Combined Chemicals in the Environment. 2025. 351-364. Chapter book.

One of the most effective ways to assess the potential health hazards of chemical interactions is through an in-depth and integrated toxicological evaluation. This chapter particularly emphasizes the mechanistic combined toxicity of the legacy and emerging environmental pollutants, both in vivo and in vitro models. Moreover, the existing challenges and future perspectives of applying experimental, analytical, and predictive models in mixture toxicity evaluation were discussed. The majority of the chemical mixtures affected the normal estrogen, thyroid, and metabolism functions, leading to oxidative stress, reproductive organ deformities, disturbed estrogen cycle, and hepatotoxicity.
Furthermore, multigenerational epigenetic effects in the form of DNA methylation were found in the F 3 and F 4 generations after mixture exposure. Moreover, analytical techniques are also being applied to investigate the interactions between chemical and biological systems; however, they can be limited by the complexity of the data and require more precision. Predictive models are becoming increasingly popular for their ability to quickly and accurately forecast the toxicity of different chemical mixtures; however, these models require validation.
Despite these challenges, the future prospects for mixture toxicology are promising, as researchers continue to refine their methods and develop new techniques, particularly machine learning–based in silico methods for evaluating the safety of different chemical combinations.
https://onlinelibrary.wiley.com/doi/abs/10.1002/9781394158355.ch19

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Liu, S. H., Manz, K.E., Buckley, J.P. Et Al.
Exposome Burden Scores to Summarize Environmental Chemical Mixtures: Creating a Fair and Common Scale for Cross-study Harmonization, Report-back and Precision Environmental Health.
Curr Envir Health Rpt 2025; Vol. 12 (13).

Environmental health researchers are increasingly concerned about characterizing exposure to environmental chemical mixtures (co-exposure to multiple chemicals simultaneously). We discuss approaches for quantifying an overall summary score or index that reflects an individual's total exposure burden to components of the mixture. We focus on unsupervised methods, in which the summary score is not computed in relation to a pre-specified health outcome.
Sum-scores and principal components analysis (PCA) are common approaches for quantifying a total exposure burden metric but have several limitations: 1) they require imputation when using exposure biomarkers with high frequency of non-detection, 2) they do not account for exposure heterogeneity, 3) sum-scores assume the same measurement error for all people, while there is no error term inherent to the PCA model as its primary purpose is dimension reduction, and 4) in pooled analyses, both approaches are limited to analyzing the set of exposure variables that are in common across all studies, potentially discarding valuable information.
Meanwhile, item response theory (IRT) is a novel and promising alternative to calculate an exposure burden score that addresses the above limitations. It allows for the inclusion of exposure analytes with high frequency of non-detects without the need for imputation. It can account for exposure heterogeneity to calculate fair metrics for all people, through assessment of differential item functioning and mixture IRT. IRT also quantifies measurement errors of the exposure burden score that are individual-specific, such that it appropriately assigns a larger standard error to an individual who has missing data on one or more exposure variables. Lastly, IRT enhances cross-study harmonization by enabling the creation of exposure burden calculators to set a common scale across studies, and allows for the inclusion of all exposure variables within a chemical class, even if they were only measured in a subset of participants.
Summarizing total exposure burden, through the creation of fair and informative index scores, is a promising tool for environmental health research as environmental exposures are increasingly used for biomonitoring and clinical recommendations.
https://doi.org/10.1007/s40572-024-00467-2

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5. Coexpositions aux métaux lourds

Beddingfield, Z., Ji, C., Zarus, G. M., Ruiz, P., Faroon, O., Abadin, H.*, et al.*
Review of Correlations Between Telomere Length and Metal Exposure Across Distinct Populations.
Environments 2024; Vol. 11 (12)

Telomere length (TL) predicts the onset of replicative senescence, and its shortening is a limiter on the number of divisions individual somatic cells can perform. Metal-induced genotoxic events are discussed in Agency for Toxic Substances and Disease Registry's (ATSDR) toxicological profiles. In vivo and in vitro toxicological studies suggest the correlation between toxic metals and TL. However, the correlation between TL and exposure to toxic metals in human populations is unclear despite decades of observational research.
We conducted a literature search within the ATSDR toxicological profiles and PubMed database for peer-reviewed articles as of 04/2023 discussing TL and metal exposure in human populations. Through review of the 272 publications meeting these criteria, we identified 25 observational studies that considered the correlation between TL and exposure to some or all of six metals: cadmium (Cd), arsenic (As), nickel (Ni), selenium (Se), lead (Pb), and cesium (Cs). Because reported effect sizes were often not comparable across studies, we performed a sign test based on the reported significance for each metal-TL correlation. We found that Cd was consistently significantly correlated with shorter telomeres ($p = 0.016$). However, no consistent linear relationship was observed between TL and any of the other metals considered. Exploring this association can enhance our understanding of how metal exposure may influence TL dysfunction. Our findings suggest that Cd exposure contributes to shorter TL, which may affect the DNA damage response (DDR) resulting in numerous chronic health conditions.
Further, we highlight inconsistencies in findings on the correlation between metal exposure and TL across different populations and exposure levels. This suggests that correlations between some metals and TL may vary across populations, and that correlations may change at different exposure levels.
Also, our findings suggest the need for further research on the potential for nonlinear relationships and non-additive effects of co-exposure to multiple hazardous metals, which could explain the inconsistencies observed across studies. The inconsistent incidences of metal-TL correlations justify additional exploration into the complex interaction between metals and TL.
https://doi.org/10.3390/environments11120280

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Chen, J., Chen, J., Li, M., Feng, P., Qin, M., Chen, T.*, et al.*
Probabilistic assessment of the cumulative risk from dietary heavy metal exposure in Chongqing, China using a hazard-driven approach.
Scientific Reports 2025; Vol. 15 (1) p 2229.

Cumulative risk assessment is significant for evaluating the combined exposure to multiple substances, but its widespread acceptance and application have been limited due to the complexity of clarifying and assessing actual exposure. In this study, we conducted a cumulative risk assessment based on hazard-driven criteria to evaluate the co-exposure to elemental contaminants in the diet of the population in Chongqing Municipality. The cumulative risk was calculated and evaluated using Monte Carlo modeling and the modified Reference Point Index (mRPI) method. Neurotoxicity and nephrotoxicity were identified as the main toxic endpoints, and the final evaluation elements included were Pb, Cd, As, and Hg.
The results showed that the combined mRPI values for neurotoxicity and nephrotoxicity, resulting from exposure to the four heavy metals, ranged from 0.922 to 4.835 and 1.306 to 7.031, respectively. Cd and Pb were the primary contributors to nephrotoxicity, while Pb was the main contributor to neurotoxicity. The

results indicated that combined dietary exposure to Pb, Cd, As, and Hg may pose risks of neurotoxicity and nephrotoxicity, with the combined exposure likely amplifying this risk compared to exposure to individual heavy metal elements.
mRPI proves to be a more suitable index for cumulative risk assessment using a hazard-driven approach compared to other indexes, as it is derived based on specific studies and endpoints.
https://doi.org/10.1038/s41598-024-83299-2

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Chen J, Z. Q., Wang Y Et Al.
Association of PM2.5-bound multiple metals co-exposure with early cardiovascular damage: A panel study in young adults combining metabolomics.
Environmental Pollution 2025; Vol. 371 (125964)

The association of individual metals in PM2.5 with cardiovascular damage has been established in previous studies, but there are fewer studies on co-exposure to multiple metals and potential metabolic alterations in cardiovascular damage. To investigate the early cardiovascular effects of multiple metals and the mediating effects of metabolites, we conducted a panel study on young adults from 2017 Winter to 2018 Autumn in Caofeidian, China.
A total of 180 serum samples were analyzed for metabolomic profiles using liquid chromatography-mass spectrometry. The associations between personal metal exposure, metabolite levels, and indicators of cardiovascular injury were analyzed by linear mixed-effects modeling (LME) and Bayesian kernel machine regression (BKMR). Metabolomic analyses showed 79 metabolites in the serum of healthy adults changed significantly between seasons and all metabolites were strongly associated with toxic metals. Additionally, differential metabolites were enriched in seven metabolic pathways and activated by metal exposure, such as Butanoate metabolism and Linoleic acid metabolism. BKMR model interpreted that the overall effect of metals mixture was negatively associated with Capryloyl glycine and Sphinganine and Sb mainly contributed to the effect.
The results of mediation analysis revealed that the association between V and VEGF was mediated by Diethylhexyl with a partial proportion of 13.4%. Furthermore, the result also found the association between CerP(d18:1/26:1(17Z)) and ET-1 was mediated by TGFβ1 with a proportion of 53.4%.
Our findings suggested that multiple metal exposure was associated with metabolomic changes of cardiovascular damage in young adults, and may simultaneously affect the metabolomic changes by inducing oxidative stress and inflammation.
https://doi.org/10.1016/j.envpol.2025.125964

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Feng, X., Luo, Y., Zheng, M., Sun, X., Shen, X.
Independent and Combined Associations between Metals Exposure and Inflammatory Markers among the General US Adults.
Environ. Health 2025, Vol 3, n°3, p :282–290

Exposure to metals can trigger a series of diseases by dysregulating the human immune system, but there is still a lack of systematic studies assessing the independent and combined effects of exposure to metals on immune function in the general population, particularly concerning inflammation markers. This cross-sectional study was designed to mainly examine the associations between urinary metal mixtures and inflammatory markers, including white blood cell (WBC), platelet count (PLT), mean platelet volume (MPV), MPV/PLT ratio (MPR), platelet-to-lymphocyte ratio (PLR), and neutrophil-to-lymphocyte ratio (NLR).
A total of 3451 participants aged >= 20 years were selected from the 2013-2016 National Health and Nutrition Examination Survey. Generalized linear models were used to investigate the relationships of exposure to single metals on inflammatory markers. Associations between coexposure to multiple metals and inflammatory markers were determined using weighted quantile sum regression and quantile g-computation. Barium, cadmium, lead, thallium, and cobalt showed significant associations with MPV, PLR, and NLR. Metal mixtures showed a negative association with MPV, while they had positive associations with

PLR and NLR.
Overall, our study highlights the significant effects of multiple metals exposure on inflammation markers, including MPV, PLR, and NLR, among U.S. adults. Thereinto, uranium, cadmium, and cobalt were identified as major contributors. Further prospective studies representative of other countries are warranted to either validate or refute our findings.
https://doi.org/10.1021/envhealth.4c00097

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González Palomo, A. K., Cortés García, J. D., Saldaña Villanueva, K., Díaz Barriga Martínez, F., Méndez Rodríguez, K. B., Alcantara Quintana, L. E.*, et al.*
Exposure to multiple heavy metals associated with levels of inflammatory cytokines in workers in vulnerable conditions.
Int Arch Occup Environ Health 98, 109-118 (2025).

Individuals in occupational environments are particularly susceptible to the impacts of pollutants; making it crucial to assess systemic inflammation markers. The study aimed to evaluate the immune response to inflammation through the assessment of a cytokine profile in individuals working in vulnerable conditions exposed to heavy metals.
Methods : A total of 137 adults participated in this study from three work environments: brickyards, waste scavenging and quarries. Levels of 12 metals were evaluated in urine using inductively coupled plasma mass spectrometry (ICP-MS), and serum levels of 6 cytokines were analyzed using Multi-Bead Cytokine Assay.
Results : In the brickyard scenario, a significant percentage of subjects presented concentrations above the reference levels of Hg, As, and Pb (83.7%, 62.8%, and 16.3%; respectively). The waste scavenging and quarry workers scenario exhibited percentages of 100% and 49% for Ni, respectively. Additionally, the brickyard and waste scavenging scenarios showed the highest levels of TNF-α and INF-γ and, lower levels of IL-4 and IL-10. In the quarry scenario, an increase of IL-6 and a decrease in INF-γ were observed. Furthermore, a clustering pattern based on the type of scenario was identified, indicating a higher exposure to As, Pb, and Hg in the brickyard scenario, along with TNF-α, IL-4, and IL-10 levels.
Conclusions : The results suggest that exposure to heavy metals in workers with precarious work conditions, present elevated levels of inflammatory cytokines, which are related to the type of occupational environment.
https://doi.org/10.1007/s00420-024-02116-5

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Haruna, I.
Association of Combined Per-and Polyfluoroalkyl Substances (PFAS) and Metals With Chronic Kidney Disease.
Int J Environ Res Public Health. 2024 Apr 11;21(4):468.

Background: Exposure to environmental pollutants such as metals and Per- and Polyfluoroalkyl Substances (PFAS) has become common and increasingly associated with a decrease in the estimated Glomerular Filtration Rate (eGFR), a marker often used to measure chronic kidney disease. However, there are limited studies involving the use of both eGFR and urine Albumin Creatinine Ratio (uACR), which are more comprehensive markers to determine the presence of CKD and the complexity of pollutant exposures and response interaction, especially for combined metals and PFAS has not been comprehensively elucidated.
Objective: This study aims to assess the individual and combined effects of Perfluorooctanoic acid (PFOA), Perfluorooctanesulfonic acid (PFOS), cadmium (Cd), mercury (Hg), and lead (Pb) exposure on CKD using data from the National Health and Nutritional Examination Survey (NHANES) 2017-2018.
Methods: We employed the use of bivariate logistic regression and Bayesian Kernel Machine Regression (BKMR) in our analysis of the data.
Results: Logistic regression results revealed a positive association between PFOA with CKD. Our BKMR analysis revealed a non-linear and bi-phasic relationship between metal exposures and CKD. In our univariate exposure-response function plot, Cd and Hg exhibited a U and N-shaped interaction, which

indicates a non-linear and non-additive relationship with both low and high exposures being associated with CKD. In addition, the bivariate exposure-response function between two exposures in a mixture revealed that Cd had a U-shaped relationship with CKD at different quantiles of Pb, Hg, PFOA, and PFOS indicating that both low and high levels of Cd are associated with CKD, implying a non-linear and complex biological interaction. Hg's interaction plot demonstrated an N-shaped association across all quantiles of Cd, the 75th quantile of Pb, 50th and 75th quantiles of PFOA and PFOS. Furthermore, the PIP results underscored Cd's consistent association with CKD (PIP=1.000) followed by Hg's (PIP=0.9984), then PFOA and PFOS with a closely related PIP of 0.7880 and 0.7604 respectively and finally Pb (PIP=0.6940) contributing the least among the five environmental pollutants on CKD, though significant.
Conclusions: Our findings revealed that exposure to environmental pollutants, particularly Hg and Cd, is associated with CKD. These findings highlight the need for public health interventions and strategies to mitigate the cumulative effect of PFAS and metal exposure and elucidate the significance of utilizing advanced statistical methods and tools to understand the impact of environmental pollutants on human health. Further research is needed to understand the mechanistic pathways of PFAS, and metal-induced kidney injury and CKD, and longitudinal studies are required to ascertain the long-term impact of these environmental exposures.
https://doi.org/10.3390/ijerph21040468

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He-Bin Chi, J.-J. T., Xiao-Yuan Fan, Han-Wen Zhang, Feng Tang, Xian-Shu Lin, Bing-Rui Yang, Na Li, Jun Guo, Li-an-Sheng Wu, Qiu-Qi Huang, Yin-Yin Xia.
Single- and combined-heavy metals/metalloids exposures are associated with infertility in US women aged 20–44: NHANES 2013–2020 analysis.
Reproductive Toxicology 2025; Vol. 132

Infertility is a major medical and social issue, with environmental factors, including metal exposure, playing a crucial role. This study analyzes how individual metals and their mixtures, which include a selection of heavy metals and metalloids totaling sixteen metals, contribute to infertility risk, using data from the National Health and Nutrition Examination Surveys.
The study included 1326 women aged 20–44 years, comprising 1145 classified as fertile and 181 as infertile, with data on reproductive questionnaires and covariates. Infertility was defined through self-reported data. To assess the associations between exposure to these elements and infertility risk, we employed logistic regression, principal component analysis (PCA), restricted cubic splines (RCS), quantile regression with group-specific combination (qgcomp), and bayesian kernel machine regression (BKMR). After adjusting for potential confounders, logistic regression revealed positive associations of blood manganese (BMn) and urinary tin (USn) with infertility, whereas serum selenium (SSe) was negatively associated. RCS analysis demonstrated nonlinear relationships between urinary barium (UBa), urinary molybdenum (UMo), and urinary antimony (USb) and infertility. Potential interactions were identified between the following metal pairs: UMo and urinary cadmium, USb and UBa, and USb and UMo. PCA identified a positive association between PC3 and infertility (OR = 1.17, 95 % CI: 1.00, 1.36). The qgcomp model also indicated a positive association between metal mixtures and female infertility (OR = 1.25, 95 % CI: 1.03, 1.52).
In conclusion, this study highlights significant associations between exposure to specific metals and infertility risk among women of reproductive age.
https://doi.org/10.1016/j.reprotox.2025.108851.

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Igor Pujalté, Z. L., Alice Bernard, Lionel Moulis, Sophie Delpoux, Jacques Gardon.
Arsenic and fifteen other metal (loid)s exposure of children living around old mines in the south of France.
Ecotoxicology and Environmental Safety 2025; Vol. 291, 117842

As many countries plan to resume mining for the energy transition, assessing the health impacts of past activities is crucial. This cross-sectional study investigated whether children living near four old mines in southern France were exposed to higher levels of arsenic and 15 other metal(loid)s compared to those in

unexposed areas. Arsenic, a prevalent contaminant, was used as an indicator to explore exposure in relation to children's lifestyles (housing, activities, diet) and their environments (soil, dust, water). The study included 240 children—138 from exposed areas and 102 from control areas. Urine samples were analyzed for inorganic arsenic, its metabolites, and other trace elements. No significant difference was found in average age, BMI, or parental education between groups. Urinary arsenic levels were similar for children living near mines and those in control areas (6.4 vs. 7.0 µg/g; p = 0.152). Proximity to mining sites did not increase arsenic exposure (r Pearson = 0.142). Instead, factors like age, seafood consumption, and environmental conditions were more influential. Children who ate seafood had higher arsenic levels in urine (p < 0.001). In a subgroup near mines, arsenic in soil and dust was significantly linked to increased exposure (p < 0.001). Overall, metal exposure levels were comparable to or lower than national averages. Access to clean water, mine closures, and health awareness likely kept exposure low. Ongoing biomonitoring is crucial for identifying and mitigating health risks in communities living near former mining areas.
https://doi.org/10.1016/j.ecoenv.2025.117842.

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Kong, X. G., Li, C., Pan, Y. W.
Association Between Heavy Metals Mixtures and Life's Essential 8 Score in General US Adults.
Cardiovascular Toxicology 2025; 25 : 592–603

Heavy metals were toxic environmental pollutants capable of entering the human body, posing significant risks to human health. Life's Essential 8 (LE8) score is a new comprehensive index constructed for quantifying cardiovascular health (CVH).
However, the association between heavy metals mixtures and LE8 appears ambiguous. To investigated the association between heavy metals and cardiovascular health in US population. Urinary heavy metals concentrations (barium, cadmium, cobalt, manganese, molybdenum, lead, antimony, strontium, thallium, tin, tungsten, uranium, cesium) were Ln-transformed and LE8 was consisted of eight metrics. Single and multivariate linear regression, weighted quantile sum (WQS) and Bayesian kernel machine regression models (BKMR) were utilized to assess the association between single and mixed exposure of thirteen heavy metals concentrations and LE8.
In 4339 participants from National Health and Nutrition Examination Survey 2007-2018, single urinary heavy metals barium, cadmium, cobalt, lead, antimony, strontium, tin, tungsten, uranium and cesium showed a significant negative association with LE8. WQS models showed heavy metals mixture was negatively associated with LE8 (beta = - 2.720, 95% CI - 3.660, - 1.790). BKMR analysis also demonstrated a downward trend of heavy metals mixture and LE8. Both WQS analyzed weights and the conditional posterior inclusion probabilities (condPIP) of BKMR showed that cadmium (37.78%, condPIP = 1.000), barium (24.56%, condPIP = 0.537) and uranium (14.71%, condPIP = 0.646) contributed most for these negative associations. Single and mixed heavy metals, especially cadmium, barium and uranium were negatively associated with LE8 score, a new comprehensive CVH index, predicting an increasing risk of cardiovascular diseases.
https://doi.org/10.1007/s12012-025-09969-3

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Lamtai, M., Benmhammed, H., Azirar, S., Rezqaoui, A., Zghari, O., El Hamzaoui, A.*, et al.*
Subchronic Exposure to Mixture of Cadmium, Copper, and Nickel Induces Neurobehavioral Deficits and Hippocampal Oxidative Stress of Wistar Rats.
Biological Trace Element Research 2025; Vol. 203 (1) p 280-290.

The present study was aimed at evaluating the influence of the subchronic exposure of cadmium (Cd), copper (Cu), and nickel (Ni) mixtures on affective behaviors, memory impairment, and oxidative stress (OS) in the hippocampus. Thirty male Wistar rats were divided into 5 equal groups. Group 1 (control) received a saline solution (NaCl 0.9%). Groups 2, 3, and 4 received Cd (0.25 mg/kg), Cu (0.5 mg/kg), and Ni (0.25 mg/kg), respectively, while group 5 received a Cd, Cu, and Ni mixture through intraperitoneal injections for 2 months. After the exposure period, all rats were submitted to behavioral tests. Subsequently, OS markers

and histological changes in the rats' hippocampi were assessed.
Results showed that a 2-month exposure to the mixtures of metals (MM) has led to higher anxiety-like and depression-like behaviors and cognitive deficits in rats when compared to the control group and the individual metals. Furthermore, the MM induced heightened OS, evidenced by the rise in lipid peroxidation and nitric oxide levels. These effects were accompanied by a decrease in superoxide dismutase and catalase activities in the hippocampus. The histopathological analysis also supported that MM caused a neuronal loss in the CA3 sub-region. Overall, this study underscores that subchronic exposure to the Cd, Cu, and Ni mixture induces an OS status and histological changes in the hippocampus, with important affective and cognitive behavior variations in rats.
https://doi.org/10.1007/s12011-024-04166-9

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Liu, Q., Bi, J., Fan, G., Wu, M., Qin, X., Fang, Q.*, et al.*
Association between multiple metals exposure and metabolic dysfunction-associated fatty liver disease among Chinese adults.
Journal of Trace Elements in Medicine and Biology 2024; Vol. 86 (12) :127566

Background: Previous research has investigated the hepatotoxicity of single metal exposure. However, there is limited evidence about metal mixture and their association with metabolic dysfunction-associated fatty liver disease (MAFLD), particularly in the Chinese population.
Objective: To investigate the individual and combine effects of 20 metals on MAFLD in a large population in China.
Methods: This study included 3651 participants from the Medical Physical Examination Center of Tongji Hospital, Wuhan, China. MAFLD was identified based on ultrasonic graphic evidence of hepatic steatosis and the presence of overweight/obese, diabetes mellitus, or metabolic dysregulation. Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine urinary concentrations of 20 metals. Logistic regression was used to assess the relationship between individual metal and MAFLD, with results presented as odds ratios (ORs) and 95 % confidence intervals (CIs). Weighted quantile sum (WQS) regression was performed to evaluate the combine effect of metals.
Results: The prevalence of MAFLD among the participants was 32.1 % (1173/3651). In singe-metal analysis, high exposure to zinc (OR =1.42; 95 % CI = 1.27, 1.59) and selenium (OR = 1.23; 95 % CI = 1.10, 1.39) were positively associated with MAFLD. No significant association was found for other metals. WQS regression analysis showed that urinary metal mixture was positively associated with MAFLD (OR = 1.32, 95 % CI: 1.15, 1.51), with zinc (50.4 %) being the largest contributor, followed by barium (10.8 %).
Conclusions: In conclusion, our finding suggested that exposure to the mixture of metals was positively correlated with MAFLD, with zinc being the major contributor.
https://doi.org/10.1016/j.jtemb.2024.127566

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Ogundare, O., Obeng-Gyasi, E.
Association of Combined Effect of Metals Exposure and Behavioral Factors on Depressive Symptoms in Women.
Toxics 2024; 12(12), 879.

This study investigates the combined effects of environmental pollutants (lead, cadmium, total mercury) and behavioral factors (alcohol consumption, smoking) on depressive symptoms in women. Data from the National Health and Nutrition Examination Survey (NHANES) 2017-2018 cycle, specifically exposure levels of heavy metals in blood samples, were used in this study. The analysis of these data included the application of descriptive statistics, linear regression, and Bayesian Kernel Machine Regression (BKMR) to explore associations between environmental exposures, behavioral factors, and depression.
The PHQ-9, a well-validated tool that assesses nine items for depressive symptoms, was used to evaluate depression severity over the prior two weeks on a 0-3 scale, with total scores ranging from 0 to 27. Exposure levels of heavy metals were measured in blood samples. BKMR was used to estimate the exposure-response

relationship, while posterior inclusion probability (PIP) in BKMR was used to quantify the likelihood that a given exposure was included in the model, reflecting its relative importance in explaining the outcome (depression) within the context of other predictors in the mixture.
A descriptive analysis showed mean total levels of lead, cadmium, and total mercury at 1.21 mu g/dL, 1.47 mu g/L, and 0.80 mu g/L, respectively, with a mean PHQ-9 score of 5.94, which corresponds to mild depressive symptoms based on the PHQ-9 scoring. Linear regression indicated positive associations between depression and lead as well as cadmium, while total mercury had a negative association. Alcohol and smoking were also positively associated with depression. These findings were not significant, but limitations in linear regression prompted a BKMR analysis. BKMR posterior inclusion probability (PIP) analysis revealed alcohol and cadmium as significant contributors to depressive symptoms, with cadmium (PIP = 0.447) and alcohol (PIP = 0.565) showing notable effects. Univariate and bivariate analyses revealed lead and total mercury's strong relationship with depression, with cadmium showing a complex pattern in the bivariate analysis.
A cumulative exposure analysis of all metals and behavioral factors concurrently demonstrated that higher quantile levels of combined exposures were associated with an increased risk of depression. Finally, a single variable-effects analysis in BKMR revealed lead, cadmium, and alcohol had a stronger impact on depression. Overall, the study findings suggest that from exposure to lead, cadmium, mercury, alcohol, and smoking, cadmium and alcohol consumption emerge as key contributors to depressive symptoms.
These results highlight the need to address both environmental and lifestyle choices in efforts to mitigate depression.
https://doi.org/10.3390/toxics12120879

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Ogundipe, E., Obeng-Gyasi, E.
Joint Effects of Lifestyle Habits and Heavy Metals Exposure on Chronic Stress Among U.S. Adults: Insights from NHANES 2017–2018.
J. Xenobiot. 2025, 15(1), 7

Background: Chronic stress, characterized by sustained activation of physiological stress response systems, is a key risk factor for numerous health conditions. Allostatic load (AL), a biomarker of cumulative physiological stress, offers a quantitative measure of this burden. Lifestyle habits such as alcohol consumption and smoking, alongside environmental exposures to toxic metals like lead, cadmium, and mercury, were individually implicated in increasing AL. However, the combined impact of these lifestyle habits and environmental factors remains underexplored, particularly in populations facing co-occurring exposures.
This study aims to investigate the joint effects of lifestyle habits and environmental factors on AL, using data from the NHANES 2017–2018 cycle. By employing linear regression and Bayesian Kernel Machine Regression (BKMR), we identify key predictors and explore interaction effects, providing new insights into how cumulative exposures contribute to chronic stress.
Results from BKMR analysis underscore the importance of addressing combined exposures, particularly the synergistic effects of cadmium and alcohol consumption, in managing physiological stress.
Methods: Descriptive statistics were calculated to summarize the dataset, and multivariate linear regression was performed to assess associations between exposures and AL. BKMR was employed to estimate exposure–response functions and posterior inclusion probabilities (PIPs), focusing on identifying key predictors of AL.
Results: Descriptive analysis indicated that the mean levels of lead, cadmium, and mercury were 1.23 µg/dL, 0.49 µg/dL, and 1.37 µg/L, respectively. The mean allostatic load was 3.57. Linear regression indicated that alcohol consumption was significantly associated with increased AL (β = 0.0933; 95% CI [0.0369, 0.1497]; p = 0.001). Other exposures, including lead (β = −0.1056; 95% CI [−0.2518 to 0.0408]; p = 0.157), cadmium (β = −0.0001, 95% CI [−0.2037 to 0.2036], p = 0.999), mercury (β = −0.0149; 95% CI [−0.1175 to 0.0877]; p = 0.773), and smoking (β = 0.0129; 95% CI [−0.0086 to 0.0345]; p = 0.508), were not significant. BKMR analysis confirmed alcohol's strong importance for AL, with a PIP of 0.9996, and highlighted a non-linear effect of cadmium (PIP = 0.7526). The interaction between alcohol and cadmium showed a stronger effect on AL at higher exposure levels. In contrast, lead, mercury, and smoking demonstrated minimal effects on AL.

Conclusions: Alcohol consumption and cadmium exposure were identified as key contributors to increased allostatic load, while other exposures showed no significant associations. These findings emphasize the importance of addressing lifestyle habits and environmental factors in managing physiological stress.
https://doi.org/10.3390/jox15010007

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Othman, H. Q., Hussein, Z. A.
Assessment of radionuclide (radon, radium, and uranium) concentrations and heavy metal levels in blood samples from workers in concrete block factories.
Journal of Radiation Research and Applied Sciences 2025; Vol. 18 (1) : 101306

This study investigates the occupational exposure of workers in concrete block factories to radionuclides (radon, radium, uranium) and heavy metals (lead, cadmium, nickel, copper, chromium) by analyzing blood samples from 20 factory workers and 20 controls residing in a clean environment in Sulaymaniyah Governorate, Iraq. Radionuclide concentrations were assessed using CR-39 track detectors, and heavy metal levels were measured using X-ray fluorescence (XRF) spectroscopy.
The average activity concentration of radon, radium, and uranium for the first group was 35.84 + 1.64 Bq.m-3 , 0.74 + 0.06 Bq.kg-1, and 8.68 + 1.04 Bq.kg-1, respectively, while for the second group, the concentrations were 12.55 + 1.42 Bq.m- 3 for radon, 0.34 + 0.04 Bq.kg-1 for radium, and 3.78 + 0.09 Bq.kg-1 for uranium. Heavy metals were also substantially elevated, with lead being the most abundant (25.12 + 3.12 ppm), followed by nickel (19.02 + 2.42 ppm) and cadmium (16.87 + 2.88 ppm), while control group levels were significantly lower. Longer employment duration correlated with increased accumulation of these toxic elements, and smoking further amplified heavy metal concentrations in blood. Despite radon levels being below the thresholds set by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), the combined exposure to radionuclides and toxic metals raises significant health concerns, including risks of respiratory and systemic toxicity.
This study highlights the urgent need for improved workplace safety measures in these industrial environments. Recommendations include the installation of effective ventilation systems, provision of personal protective equipment (PPE), regular health monitoring, and training programs for workers on safe practices to minimize exposure. These measures are critical for mitigating the long-term health risks posed by occupational exposure to radiation and heavy metals in concrete block factories and ensuring worker safety.
https://doi.org/10.1016/j.jrras.2025.101306

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Song, Y., He, L., Zhang, L., Jin, Z., Zhang, L., Liu, Y.
Role of kidney function in mediating the relationship between heavy metal exposure and all-cause mortality in older adults.
Human and Ecological Risk Assessment: An International Journal 2025; Vol. 31 (1-2) p 300-312.

Heavy metal exposure has well-established health risks, but its impact on all-cause mortality through renal function remains unclear. This study used data from 1,342 participants aged≥60 years in the National Health and Nutrition Examination Survey (2005-2018).
A cross-sectional design was employed, with heavy metal composite scores derived using least absolute shrinkage and selection operator regression. Multivariate Cox proportional hazards models assessed the relationship between heavy metal exposure and all-cause mortality, while mediation analysis evaluated the role of estimated glomerular filtration rate (eGFR). The average participant age was 69.4 years. Higher composite metal exposure scores (CMES) were associated with older age, higher smoking rates, and increased blood lead (Pb) and cadmium (Cd) levels. CMES was significantly associated with mortality (adjusted HR=1.75, 95% CI:1.04-2.96), with Kaplan-Meier curves showing lower survival in participants with higher CMES (p=0.02). Pb and Cd levels were independently associated with increased mortality risk. eGFR was negatively correlated with mortality (adjusted HR=0.98, 95% CI: 0.97-0.99) and mediated 23.7% of the CMES-mortality relationship.

These findings suggest that heavy metal exposure increases mortality risk, partly through impaired renal function.
https://doi.org/10.1080/10807039.2024.2446255

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Taylor, R. M., Ali, A.-M. S., Zhu, Y., Bolt, A. M., Baca, J. T.
Advancements in Heavy Metal Detection Using Microneedle Array Technology.
Toxicology mechanisms and methods 2025; Vol.,p 1-16.

Heavy metal and metalloid (HM) exposure poses significant health risks, including cardiovascular disease, cancer, and renal damage. This contamination, prevalent in the Western U.S., involves Arsenic (As), Cadmium (Cd), Uranium (U), and Vanadium (V). Interstitial fluid (ISF) is a source of biomarkers, which can be minimally invasively collected using microneedle array (MA) technology.
Our study hypothesized that MA-extracted ISF would facilitate non-invasive HM quantification. We established analytical parameters for HM detection in ISF using inductively coupled plasma-mass spectrometry (ICP-MS), defined baseline ISF HM concentrations in unexposed animal populations, and monitored HM levels in ISF under mixed exposure in animal models.
Additionally, we assessed HM levels in ISF and biological fluids from three human subjects. Thirty-six Sprague Dawley rats were divided into cohorts: low-level mixed HMs exposure (5X maximum contaminant level (MCL)); high-level single HM with low-level others (50X MCL for one HM with 5X for others); and unexposed controls. ISF and plasma were collected weekly for eight weeks and analyzed via ICP-MS.
Our findings reveal a correlation between ISF and plasma HM levels, underscoring ISF's potential for real-time monitoring of HM exposure. This study also establishes baseline ISF HM levels, illustrating the feasibility of HM quantification using small ISF volumes.
https://doi.org/10.1080/15376516.2025.2461647

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Teng, K., Guan, Q., Liu, Q., Mo, X., Luo, L., Rong, J.*, et al.*
Association Between Urinary Metal Levels and Chronic Kidney Dysfunction in Rural China: A Study on Sex-Specific Differences.
Toxics 2025. 13(1), 55
Background: While current epidemiological studies have documented associations between environmental metals and renal dysfunction, the majority have concentrated on plasma metal levels. The relationship between urinary metal exposure and chronic kidney disease (CKD) remains contentious, particularly within specific demographic groups.
Methods: This cross-sectional study included 2919 rural Chinese adults recruited between 2018 and 2019. Urine metals were measured by ICP-MS. Least absolute shrinkage and selection operator (LASSO) regression was employed to identify metals significantly associated with CKD. Then, we used binary logistic regression, along with restricted cubic spline (RCS) models, to assess the individual exposure effects of specific metals on CKD. Quantile g-computation, weighted quantile sum regression, and Bayesian kernel machine regression (BKMR) models were applied to evaluate combined effects of metal exposures on CKD. Gender-stratified analyses were also conducted to explore these associations. Results: LASSO identified seven metals (V, Cu, Rb, Sr, Ba, W, Pb) with significant impacts on CKD. In single-metal models, Cu and W exhibited a positive correlation with CKD, whereas V, Rb, Sr, Ba, and Pb showed significant negative correlations (all $p < 0.05$). RCS analysis revealed nonlinear associations between V, Cu, Ba, Pb, and CKD (all p-nonlinear < 0.05). In the multi-metal model, quantile-based g-computation demonstrated a collective negative association with CKD risk for the seven mixed urinary metal exposures (OR (95% CI) = −0.430 (−0.656, −0.204); $p < 0.001$), with V, Rb, Sr, Ba, and Pb contributing to this effect. The WQS model analysis further confirmed this joint negative association (OR (95% CI): −0.885 (−1.083, −0.899); $p < 0.001$), with V as the main contributor. BKMR model analysis indicated an overall negative impact of the metal mixture on CKD risk. Interactions may exist between V and Cu, as well as Cu and Sr and Pb. The female subgroup in the BKMR model demonstrated consistency with the overall association.
Conclusions: Our study findings demonstrate a negative association between the urinary metal mixture and

CKD risk, particularly notable in females. Joint exposure to multiple urinary metals may involve synergistic or antagonistic interactions influencing renal function. Further research is needed to validate these observations and elucidate underlying mechanisms.
https://doi.org/10.3390/toxics13010055

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Wang, J., Zhang, X., Zeng, Y., Xu, J., Zhang, Y., Lu, X., Wang, F.
Mo and Sn exposure associated with the increased of bone mineral density.
Biometals 38, 559–572 (2025).

Bone mineral density (BMD) measured by T-score is strongly associated with bone health, but research on its association with metals in humans body remains limited. To investigate the relationship between metal exposure and BMD, numbers of 159 participants in eastern China were studied.
Urine and blood samples were collected and levels of 20 metals in the samples were measured using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Binary Logistic Regression model (BLR) and Generalized Linear Models (GLM) were used to explore the relationship between metals and BMD. Bayesian Kernel Machine Regression (BKMR) model was further used to explore the effect of multiple metal interactions on BMD. Six metals (Mn, Co, As, Se, Mo, Cd) were selected and the concentrations in blood and urine were compared using Wilcoxon and Spearman tests.
In the single-metal model, BLR and GLM commonly showed positive significant correlations between four metals (As, Mo, Se, Sn) in urine and BMD. Strong correlations between five metals (Mn, Co, As, Se, Mo) in blood and urine were observed ($P \leq 0.05$).
The BKMR model indicated a predominant synergistic effect of urine Mo and Sn, increased co-exposure to these metals is associated with a higher trend of BMD. These findings suggest that exposure to metals is associated with an increased level of BMD in humans. To better understand the impact of metals on bone health, further investigation into the common roles of these metals and their interactions is needed.
https://doi.org/10.1007/s10534-024-00662-6

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Yang, S., Liang, Z., Qiu, Y. Et Al.
Association entre les métaux lourds et le risque de maladies cardiovasculaires chez les adultes américains atteints de prédiabète de NHANES 2011-2018.
BMC Santé publique 2025; Vol. 25 (391)

L'association des métaux plasmatiques sur le risque de maladies cardiovasculaires (MCV) chez les adultes atteints de prédiabète reste peu étudiée. Évaluer l'association entre l'exposition au plasma métallique et le risque de MCV chez les adultes prédiabétiques aux États-Unis en utilisant cinq métaux plasmatiques.
Méthode : Cinq cycles de données (2011-2012, 2013-2014, 2015-2016 et 2017-2018) de la NHANES ont été adoptés dans cette étude. Les métaux plasmatiques ont été mesurés chez 1088 participants atteints de prédiabète. Nous avons utilisé la régression logistique multivariée, le WQS et les modèles BKMR pour évaluer les associations entre les cinq métaux plasmatiques et le risque de MCV.
Résultats : Le risque de MCV chez les participants atteints de prédiabète s'est avéré lié au 2e quartile, au 3e et au 4e quartiles de cadmium sur la base d'un modèle logistique multivarié (RC = 3,03, IC à 95 % : 1,17 à 7,82, P<0,01). De plus, l'effet conjoint des cinq métaux sur le risque de participants atteints de MCV atteints de prédiabète a été dévoilé à l'aide de modèles WQS et BKMR (OR = 1,79, IC à 95 % : 1,15-2,77, P<0,01). De plus, lorsque les concentrations des quatre autres métaux ont été contrôlées aux 25e, 50e et 75e centiles, le cadmium avait une association positive statistiquement significative avec le risque de MCV.
Conclusion : L'exposition aux métaux documentée par les cinq métaux est liée au risque de MCV chez les participants atteints de prédiabète aux États-Unis. Parmi les cinq métaux, le cadmium est celui qui est le plus fortement associé au risque de MCV chez les participants atteints de prédiabète.
https://doi.org/10.1186/s12889-025-21552-7

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Zhang, J., Ma, H., Yang, Y., Liu, L., Luo, D., Yu, D., Chen, T.
Iron-lead mixed exposure causes bone damage in mice: A multi-omics analysis.
Ecotoxicology and environmental safety 2025; Vol. 292 (117967).

Excessive intake of essential and toxic metals affects the pathological process of osteoporosis. At present, the effects of single forms of iron (Fe), lead (Pb) and other metals on bone injury have been widely studied. However, these metal elements usually do not exist in the environment in a separate form. They are ingested in various ways and are often found together in the human body. However, the mechanism of bone damage caused by Fe and Pb mixed exposure is still unclear at this stage.
At present, the combined analysis of multi-omics is the conventional method to explore the molecular mechanism behind the disease. Therefore, we attempted to combine proteomics and metabolomics to explain the mechanism of bone damage caused by mixed Fe and Pb exposure. Differential proteins and metabolites were found to be predominantly enriched in the JAK-STAT signalling pathway, inflammatory bowel disease (IBD), and osteoclast differentiation. Combined analysis showed that Fpr2, Lifr, Lisofylline, 7-Ketocholesterol, LacCer (d18: 1/14:0) and other substances may be involved in the process of bone injury mediated by mixed metal exposure.
In summary, we hypothesise that mixed exposure to Fe and Pb leads to osteoclast activation via the JAK-STAT signalling pathway in situ and indirectly via the gut-bone axis, resulting in bone damage. In general, our study potentially suggests that bone injury induced by mixed exposure of Fe and Pb may be related to osteoclast proliferation mediated by changes in inflammatory levels in vivo.
https://doi.org/10.1016/j.ecoenv.2025.117967

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Zhang, Y., Chen, C., Wu, S., Nie, C., Hu, Y., Zhong, J., Hong, F.
Analysis of the association between mixed exposure to multiple metals and comorbidity of osteopenia or osteoporosis: baseline data from the Chinese Multi-Ethnic Cohort study (CMEC).
Bmc Public Health 2025; Vol. 25 (1), 680.

Both osteoporosis and metal exposure are well-recognized public health concerns globally, particularly in the aging population. However, studies investigating the relationship between metal exposure and bone health conditions such as osteopenia and osteoporosis have either produced inconsistent results or are scarce, especially among the ethnic minorities in China.
Herein, we correlated single-metal and metal mixture exposure with osteopenia and osteoporosis using a log-binomial regression model and quantile g-computation. In total, 9,206 ethnic Chinese individuals (Dong and Miao) aged 30-79 years were investigated in this study utilizing the baseline data from the Chinese multi-ethnic cohort study. In the single-metal exposure model, urinary concentrations of arsenic (As), cadmium (Cd), chromium (Cr), iron(Fe), mercury(Hg), and manganese (Mn) were positively associated with of osteopenia, whereas those of cobalt(Co) and zinc(Zn) concentrations were negatively associated.
Additionally, urinary As, Cd, Cr, and Mn concentrations were positively associated with osteoporosis, whereas that of vanadium(V) was negatively associated.
Furthermore, Quantile g-computation results indicated that metal mixture exposure was positively associated with both osteopenia and osteoporosis. Altogether, these findings suggest that simultaneous exposure to multiple metals can affect bone health, providing a theoretical basis for further studies on underlying complex mechanisms.
https://doi.org/10.1186/s12889-025-21825-1

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6. Multiple expositions aux pesticides, VOCs et santé

Yang, Q. R., Zhang, J. F., Fan, Z. L.
Association between volatile organic compounds exposure and infertility risk among American women aged 18-45 years from NHANES 2013-2020.
Scientific Reports 2024; Vol. 14 (1) Article number: 30711

The risk of infertility is progressively escalating over the years, and it has been established that exposure to environmental pollutants is closely linked to infertility. As a prevalent environmental pollutant in daily life, there is still a lack of substantial evidence on the association between volatile organic compounds (VOCs) exposure and infertility risk.
This study aimed to examine the association between VOCs exposure and the risk of female infertility in the United States. Participant data sets from three cycles (2013-2020) were collected and downloaded from the National Health and Nutrition Examination Survey (NHANES), including demographics, examination, laboratory and questionnaire data.
The baseline characteristics of the included population were evaluated, and the weighted quartile logistic regression was used to analyze the association between the urinary metabolites of VOCs (mVOCs) levels and the risk of infertility. Further exploration of the relationship between mVOCs and infertility was conducted by using 35 and 25 as the cut-off points for age and BMI subgroup analyses, respectively. Restricted cubic spline (RCS) was employed to elucidate the nonlinear relationship between mVOCs and infertility risk. Additionally, the Bayesian kernel machine regression (BKMR) model with 20,000 iterations was applied to elucidate the link between mVOCs and the risk of infertility when exposed to mixed or individual mVOCs.
A total of 1082 women aged 18 to 45 years were included in this study, with 133 in the infertility group and 949 in the control group. The analysis of baseline characteristics suggested that urinary 34MHA, AMCC and DHBMA levels were significantly higher in the infertility group compared to the control group ($p < 0.05$). Quartile logistic regression analysis indicated that AAMA (Q3), AMCC (Q4), CYMA (Q3) and HPMMA (Q3) were positively associated with infertility risk in all models ($p < 0.05$). Subgroup analysis revealed different risk factors for infertility among various subgroups, with CYMA consistently showing a positive correlation with infertility risk in two age subgroups ($p < 0.05$). Furthermore, the association between mVOCs and infertility was observed only in the subgroup with BMI >= 25 kg/m(2). RCS analysis indicated that 2MHA, ATCA, BMA, BPMA, CYMA, 2HPMA, 3HPMA and PGA exhibited linear dose-response relationships with infertility ($p > 0.05$), while the remaining variables showed nonlinear relationships ($p < 0.05$). The BKMR model demonstrated that the risk of female infertility exhibited an increasing trend with the accumulation of mVOCs co-exposure. A positive association between the exposure to mVOCs represented by 34MHA and AMCC and the risk of infertility was observed in this research. However, the inherent limitations associated with the cross-sectional study design necessitate the pursuit of additional prospective and experimental research to further elucidate and validate the relationships between various mVOCs exposure and female infertility.
https://doi.org/10.1038/s41598-024-80277-6

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Petit, P., Berger, F., Bonneterre, V., Vuillerme, N.
Investigating Parkinson's disease risk across farming activities using data mining and large-scale administrative health data.
NPJ Parkinson's disease 2025; Vol. 11 (1) ; 13.

The risk of Parkinson's disease (PD) associated with farming has received considerable attention, in particular for pesticide exposure. However, data on PD risk associated with specific farming activities is lacking. We aimed to explore whether specific farming activities exhibited a higher risk of PD than others among the entire French farm manager (FM) population. A secondary analysis of real-world administrative insurance claim data and electronic health/medical records (TRACTOR project) was conducted to estimate

PD risk for 26 farming activities using data mining. PD cases were identified through chronic disease declarations and antiparkinsonian drug claims.
There were 8845 PD cases among 1,088,561 FMs. The highest-risk group included FMs engaged in pig farming, cattle farming, truck farming, fruit arboriculture, and crop farming, with mean hazard ratios (HRs) ranging from 1.22 to 1.67. The lowest-risk group included all activities involving horses and small animals, as well as gardening, landscaping and reforestation companies (mean HRs: 0.48-0.81). Our findings represent a preliminary work that suggests the potential involvement of occupational risk factors related to farming in PD onset and development.
Future research focusing on farmers engaged in high-risk farming activities will allow to uncover potential occupational factors by better characterizing the farming exposome, which could improve PD surveillance among farmers.
https://doi.org/10.1038/s41531-024-00864-2

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Zhu, X. D., Chen, C. X., Liu, Q., Zhu, Z. H., Wu, X. L., Zhang, Y. Q.
Multiple pesticide exposure and impaired glucose regulation in US non-diabetic population.
Environmental Pollution 2025; Vol. 366, 125519.

Prediabetes is a serious metabolic disorder that is often overlooked and 70% of individuals with prediabetes would eventually develop type 2 diabetes. The diabetogenic effects of pesticides have been reported in toxicological studies but their association with prediabetes is rarely investigated. We aimed to evaluate the association between pesticide exposure and impaired glucose regulation (IGR), including prediabetes (defined as impaired fasting glucose [IFG] and/or impaired glucose tolerance [IGT]) and insulin resistance, in a general U.S. nondiabetic population. Three classes of urinary pesticides, including organophosphorus pesticides (OPs), pyrethroid, and herbicides were measured. Generalized linear regression, restricted cubic spline, and Bayesian kernel machine regression (BKMR) models were combined to evaluate their associations. 3,5,6-trichloropyridinol (TCPY) was positively associated with prediabetes and IGT (highest vs lowest TCPY quartile: prediabetes: OR: 1.97, 95% CI: 1.18, 3.31; IGT: OR: 2.03, 95% CI: 1.14, 3.66) in a linear dose-response manner (P for nonlinear<0.05). Another two metabolites of OPs, malathion dicarboxylic acid (MDCA) diacid and para-nitrophenol (PNP), were found to increase the odds ratio of insulin resistance (PNP: OR: 1.22, 95% CI: 1.05, 1.42; MDCA: OR: 1.36, 95% CI: 1.08, 1.70) with linear dose-response curves (P for nonlinear<0.05). Considering mutual exposure to multiple pesticides, TCPY, MDCA, and PNP made the most contributions in the mixture exposure and IGR. No obvious interactions among pesticides were found in the multiple exposure settings. The odds ratio of TCPY exposure and prediabetes was increased with advancing age but not related to body mass index (BMI). The results remained robust in sensitivity analysis with restricted participants without abnormal urinary creatinine and unsteady glucose or insulin levels. Our findings suggested the close relationship between OPs and impaired glucose regulation, especially in older adults, which provides insights into the prevention of diabetes at the earlier stage.
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Gu, C. Y., Yao, T., Dong, C. X., Chen, Z. H., Wei, W. T., Li, X. J.*, et al.*
Inflammation mediates the adverse effects of urinary phthalate exposure on metabolic disease risk: Results from NHANES 2005-2016.
Ecotoxicology and Environmental Safety 2025; Vol. 290 ; 117577

Background: Phthalates are a category of chemicals commonly utilized in various industrial applications and everyday products. Their associations with health issues remains a significant concern. Although some studies have suggested associations between phthalates and metabolic diseases, the current understanding of the associations is still limited, especially the lack of effects of mixed exposure. Methods: This cross-sectional study included information from 9217 participants in National Health and Nutrition Examination Survey (NHANES) from 2005 to 2016. Multivariate logistic regression was used to explore the associations between single phthalate exposure and obesity and its complications. Weighted quantile sum (WQS)

regression and Quantile G-Computation (Qgcomp) models were used to further analyze the associations between mixed phthalate exposure and obesity and its complications. Mediated analysis was used to explore the mediating role of immune cells in the relationship between phthalate exposure and obesity and its complications.
Results: MiBP, MCOP and MBzP were associated with an increased risk of obesity. MiBP and MCOP were associated with an increased risk of abdominal obesity. MCNP, MCOP, MEHHP, MEOHP and MECPP were positively associated with T2DM. Mixed phthalate exposure was positively associated with obesity and T2DM. Monocytes mediated the effects of MiBP, MEHP and MBzP on obesity, explaining 7.94 %, -2.32 % and 6.69% of the total effect, respectively.
Conclusions: This study revealed a significant association between mixed phthalate exposure and obesity and its complications, underlining the importance of considering the interactions of these compounds. The synergistic effects of multiple phthalates may exacerbate health risks.
https://doi.org/10.1016/j.ecoenv.2024.117577

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Wang, Y., Jiang, Z., Lei, J., Tan, Z., Wu, Y., Hu, Y., *et al.*
Correlation of volatile organic chemical exposure with uric acid metabolism among US population: A cross-sectional study from NHANES program.
Journal of Environmental Sciences 2025; Vol. 152 p 611-622.

Volatile organic chemicals (VOC) have been identified as hazardous pollutants impairing human health. While whether the VOC exposure was associated with hyperuricemia is yet clarified. All the data was acquired from 6 survey cycles of the National Health and Nutrition Examination Survey (NHANES) program (2005-2006, 2011-2012, 2013-2014, 2015-2016, 2017-2018, 2017-2020). Hyperuricemia was defined as a serum uric acid (SUA) concentration exceeding 7 mg/mL in men or 6 mg/mL in women. Three quantile logistic regression models with varied covariates were developed to analyze the correlation between hyperuricemia and volatile organic chemical metabolites (VOCs) in urine, and three quantile linear regression models were used for examining the correlation between VOCs and SUA. N-acetyl-S(2-carboxyethyl)-l-cysteine (CEMA), N-acetyl-S-(3,4-dihydroxybutyl)-l-cysteine (DHBM), and phenylglyoxylic acid (PHGA) were identified to associated positively with increased hyperuricemia risk and uric acid level. Meanwhile, the weighted quantile sum (WQS) model suggested a positive association between VOCs exposure and hyperuricemia. These data indicate that VOC exposure potentially increases hyperuricemia risk, necessitating policies to mitigate VOC exposure.

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Rodriguez-Zamora, M. G., Fuhrimann, S., Winkler, M. S., Rosa, M. J., Reich, B., Lindh, C., Mora, A. M.
Respiratory and allergic outcomes among farmworkers exposed to pesticides in Costa Rica.
The Science of the total environment 2024; Vol. 954 p 176776.

AIM: We examined the association of exposure to a pesticide mixture with respiratory and allergic outcomes among farmworkers from Costa Rica.
METHODS: We conducted a cross-sectional study of 299 farmworkers between May and August 2016. We collected information on sociodemographic factors, pesticide use, and the presence of respiratory and allergic symptoms during the last 12months via questionnaire. We calculated specific gravity-adjusted average concentrations of 15 pesticide biomarkers measured in urine samples collected during two visits (4-5weeks apart). We fitted "traditional" Bayesian and Bayesian Weighted Quantile Sum (BWQS) regression models to assess the association of exposure to independent and summed pesticide mixture components with the outcomes of interest. We adjusted all models for age and smoking status.
RESULTS: In "traditional" Bayesian analyses, higher urinary concentrations of 2-isopropyl-4-methyl-6-hydroxypyrimidine (IMPY, metabolite of organophosphate insecticide diazinon) were associated with

increased odds of a higher asthma symptom score [adjusted OR per two-fold increase in concentrations=1.15; 95% credible interval (CrI): 1.04, 1.27)], asthma symptoms or medication use (aOR=1.37; 95% CrI: 1.13, 1.67), and rhinitis (aOR=1.34; 95% CrI: 1.15, 1.56). Higher urinary concentrations of boscalid-5-hydroxy (metabolite of fungicide boscalid) were associated with increased odds of asthma symptoms or medication use (aOR=1.24; 95% CrI: 1.00, 1.55), whereas higher concentrations of 4-hydroxypyrimethanil (metabolite of the fungicide pyrimethanil) were associated with increased odds of eczema (aOR=1.11; 95% CrI: 0.99, 1.24). Several inverse associations of herbicide concentrations with respiratory and allergic outcomes were observed. In BWQS analyses, a positive association was found between exposure to the pesticide mixture and increased odds of rhinitis (aOR=1.96; 95% CrI: 1.14, 3.20), with IMPY being the largest contributor.
CONCLUSION: Our findings indicate that exposure to pesticides may have both independent and summed mixture effects on respiratory and allergic health among farmworkers.
https://doi.org/10.1016/j.scitotenv.2024.176776

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He, H., Sun, Z., Chen, X., Tao, X., Tao, M., Dong, D.*, et al.*
Exposure to volatile organic compounds and suicidal ideation: Insights from a U.S. population-based study.
Journal of affective disorders 2025; Vol. 379 p 194-203.

BACKGROUND: Exposure to volatile organic compounds (VOCs) has been increasingly linked to mental health disorders, but the relationship between VOCs exposure and suicidal ideation (SI) remains unclear. This study aims to investigate the link between VOCs exposure and the prevalence of SI.
METHODS: We analyzed data from 6966 participants in the 2005-2020 National Health and Nutrition Examination Survey. SI was assessed using the ninth item of the Patient Health Questionnaire-9. Key urinary metabolites of VOCs (mVOCs) associated with SI were identified using elastic net regression models. Multivariate logistic regression and restricted cubic spline were used to explore associations between individual mVOCs and SI. To evaluate the impact of mVOCs mixtures on SI, we applied Environmental Risk Score and Weighted Quantile Sum models. Mediation analysis was conducted to determine whether inflammation and oxidative stress pathways contribute to the observed associations.
RESULTS: Among the participants, 253 reported SI. Across various models, only the urinary N-Acetyl-S-(2-cyanoethyl)-L-cysteine (CYMA) consistently showed a significant linear association with SI. Mixture analyses indicated a significant positive association between mVOCs mixtures and SI prevalence. Mediation analysis suggested that inflammation and oxidative stress are unlikely to be the primary mechanisms linking mVOCs exposure to SI.
CONCLUSION: This study provides the first epidemiological evidence of an association between mVOCs exposure and SI. CYMA was identified as the most critical mVOCs influencing SI. The findings suggest that the link between mVOCs exposure and SI does not primarily involve inflammation or oxidative stress pathways.
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