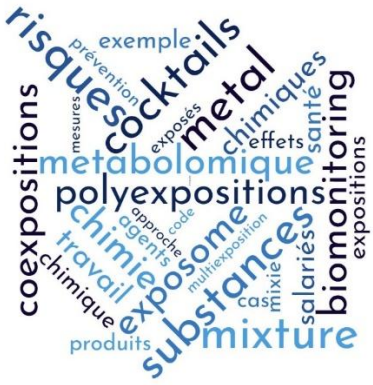

Bulletin de veille
Polyexpositions chimiques
N°15, mai-juin 2026

Objectif : la polyexposition 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 co-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 vues

- 3 mai 2026. Un réseau européen de laboratoires va répertorier l'ensemble des contaminants présents dans des échantillons biologiques du corps humain.
  En savoir plus

- 28 mai 2026. Ordre des pharmaciens. Actualités Anses du 12 mai.
  Exposition des salariés de l'industrie du médicament aux principes actifs chimiques : mieux évaluer les risques.
  Du développement des médicaments à leur conditionnement, en passant par leur fabrication, les salariés de l'industrie pharmaceutique humaine et vétérinaire peuvent être exposés aux substances chimiques qu'ils contiennent. L'Anses publie une série de recommandations à destination des employeurs afin de mieux évaluer les risques pour la santé de ces travailleurs. En savoir plus

- 27 mai. Près de 30% des travailleurs des secteurs des soins médico-sociaux en Europe sont exposés au risque de cancers professionnels, selon une enquête menée par l'Agence européenne pour la sécurité et la santé au travail (EU-OSHA). L'étude identifie des expositions combinées, telles que les émissions de diesel associées au rayonnement solaire, ou une exposition simultanée au formaldéhyde et à l'oxyde d'éthylène. Pour en savoir plus.
  Lien vers la publication

- 8 juin 2026. Ouest France (site web). **Santé. Cette nouvelle approche scientifique pour recenser tous les polluants qui circulent dans le corps humain.**
  Michel Samson dirige à Rennes l'Irset, l'un des instituts de recherche les plus réputés en France explorant tous ces sujets. Le chercheur milite pour appliquer une nouvelle approche : l'exposome.
  Lien vers l'article

Sommaire

1. Généralités. Expositions multiples chimiques

Wolf, J., Maccanti, G., Clermont, H., Limame, M. C., Thebaud Mony, A., Hunsmann, M., *et al.*
Cancers professionnels et activités de nettoyage : identifier les expositions, agir pour la reconnaissance et la prévention.
Archives des Maladies Professionnelles et de l'Environnement, Vol. 87 (2), April 2026, 103074.

Depuis 2018, le Groupement d'intérêt scientifique sur les cancers d'origine professionnelle et environnementale dans le Vaucluse (GISCOPE 84) mène une enquête systématique sur les expositions professionnelles de patient.es atteint.es de lymphomes non hodgkiniens ou de myélomes multiples suivi.es par le Groupement hospitalier de territoire du Vaucluse. La démarche est fondée sur la reconstitution fine des parcours professionnels et sur l'expertise de ces parcours par un collectif pluridisciplinaire, qui identifie et caractérise les expositions cancérogènes grâce à la description de l'activité réelle de travail pour chaque poste occupé. Face aux constats suivants, le GISCOPE a constitué un groupe de travail sur les activités de nettoyage, d'hygiène et de stérilisation.
https://doi.org/10.1016/j.admp.2026.103074

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DOYEN V. ; WALUSIAK-SKORUPA J. ; WISZNIEWSKA M. ; VANDENPLAS O. ; ET COLL.

Occupational asthma due to hair dyes containing para-amino compounds. (Asthme professionnel dû aux colorants capillaires contenant des composés para-aminés).

American Journal of Industrial Medicine, vol. 69, n° 1, janvier 2026, pp. 42-48, ill., bibliogr. (En anglais)

Cette étude européenne décrit des cas d'asthme professionnel chez des coiffeurs exposés à des teintures capillaires contenant des composés para-aminés (PACs). Neuf cas confirmés par épreuve de provocation spécifique ont montré des réactions bronchiques variées et, dans certains cas, une augmentation de l'hyperréactivité bronchique après exposition, sans élévation nette des marqueurs inflammatoires. Les résultats indiquent que les teintures oxydatives à base de PACs constituent une cause significative d'asthme professionnel et doivent être systématiquement considérées lors de l'évaluation de symptômes respiratoires liés au travail.

Référence INRS-biblio : 769999

Lien vers l'article : https://doi.org/10.1002/ajim.70037

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Liu, Y. H., Du, J., Zhang, L., Ren, J. L., Zhao, Y. Z., Jin, Y. S.*, et al.*

Individual and Joint Association of Phenol and Paraben Exposure with Asthma Outcomes among US Adults : A Nationally Representative Cross-sectional Study.

Biomedical and environmental sciences : BES, Vol. 39 (3), (2026), 297-309.

Objective: Exposure to mixtures of environmental chemicals may influence asthma outcomes; however, the evidence remains equivocal. This study aimed to assess the association between mixed exposure to phenols and parabens and asthma outcomes in adults and to explore the mediating role of body mass index (BMI).
Methods: Based on data from the National Health and Nutrition Examination Survey (NHANES, 2013-2016), this study used multivariate generalized linear regression and weighted quantile sum (WQS) regression models to evaluate the associations between individual and joint exposure to phenols and parabens and asthma outcomes. These associations were further analyzed and stratified according to age and BMI. A mediation effect analysis was used to assess the role of BMI in this association.
Results: This study included 2,556 adults, of whom 400 (15.7%) were diagnosed with asthma. After adjusting for all covariates, a significant positive correlation was observed between the chemical mixture and asthma, with an odds ratio of 1.33 (95% confidence interval, 1.06-1.68). Among the eight phenols and parabens, bisphenol F (BPF), propylparaben (PrP), and bisphenol S (BPS) were the major contributors. Additionally, BMI mediated 15.5% of the association between BPF exposure and asthma.
Conclusion: In this cross-sectional study, mixed exposure to phenols and parabens was significantly associated with asthma outcomes, with BPF, PrP, and BPS identified as the primary contributing chemicals. This study provides valuable insights into the association between mixed chemical exposure and asthma as well as potential control pathways.
https://doi.org/10.3967/bes2025.163

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Lee, D., Lee, K., Lee, S.

Large language model-based screening of substances and their composition from safety data sheets for high-resolution chemical exposure assessment.

Journal of Exposure Science and Environmental Epidemiology, Published: 13 May 2026

Background : SDSs provide information on chemical substances in professional and consumer products. Large language models (LLMs) offer a rapid approach to screening chemical information from SDSs. Objective : This study aimed to validate the performance of LLMs in accurately extracting substance

information from SDSs of products.
Methods : Chemical information was extracted from the SDSs of cleaning products using the LLMs ChatGPT-4o and Gemini 2.5 Pro. The performance of the LLMs was evaluated against manually extracted data using precision, sensitivity, and F1 score.
Results : A total of 301 substance-composition combinations across 59 products were included in the validation. The Gemini 2.5 Pro model showed a higher F1 score (1.00) than ChatGPT-4o (0.94). Significance LLMs enable high-throughput chemical information extraction from SDSs, reducing the burden of manual screening and supporting large-scale combined-exposure assessments. Impact Statement The accurate identification of chemical substances in professional and consumer products is a major challenge in assessing complex chemical exposures in exposure science and epidemiology.
This study validated the use of Large Language Models (LLMs) as a novel, rapid, and highly accurate method of extracting high-throughput chemical data from multilingual Safety Data Sheets. Our findings illustrated that LLMs could be effectively used to overcome the labor-intensive and time-consuming limitations of manual data screening. This approach allows high-throughput analysis, enabling comprehensive combined-exposure assessments in large-scale epidemiological and exposure assessment studies. Additionally, as LLMs can extract data in different languages, they can facilitate international research collaboration.
https://doi.org/10.1038/s41370-026-00917-z

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Clerc, F., Barbey, C., Aachimi, A., Bonvallot, N., Chatelot, J., Homère, J.*, et al.*
Utilisation de dix bases de données françaises pour l'analyse des polyexpositions des travailleurs.
Archives des Maladies Professionnelles et de l'Environnement, Vol. **87** (6), November 2026, 103039.

Plusieurs acteurs de la santé au travail en France organisent la collecte, la production ou bien colligent des données de santé et/ou d'exposition au travail. Les données des bases de l'enquête Surveillance médicale des expositions des salariés aux risques professionnels (Sumer), du Réseau national de vigilance et de prévention des pathologies professionnelles et environnementales (RNV3PE), de l'observatoire Évolutions et relations en santé au travail (Evrest), des matrices emplois-expositions MatGéné, du programme de surveillance Maladies à caractère professionnel (MCP), des bases de données d'exposition de l'INRS (Colchic, Scola, Colphy), du Compte professionnel de prévention (C2P) et les données de sinistralité de la Caisse nationale de l'Assurance maladie (Cnam) sont utilisées par leurs propriétaires respectifs avec des objectifs variés. Il peut s'agir notamment d'améliorer la reconstitution de parcours professionnels des travailleurs, d'aider les entreprises à mieux identifier et prévenir leurs risques, d'orienter des politiques de prévention des risques professionnels, de documenter l'impact sanitaire des expositions professionnelles ou, à des fins d'expertise, de détecter des risques émergents en santé au travail. Ces bases ne sont pas conçues pour être exploitées conjointement. Toutefois, les informations, de nature différente qu'elles contiennent, peuvent contribuer à mieux connaître les risques professionnels et notamment ceux liés à la polyexposition.
Objectif : Démontrer la faisabilité de combiner les données disponibles dans ces bases de données afin d'améliorer les connaissances au sujet de la polyexposition en milieu professionnel et présenter des éléments de résultats.
Méthode : Les caractéristiques des dix bases de données sont mises en perspective : objectif de collecte ou de production, population d'intérêt, types d'expositions et/ou de pathologies, unité statistique et nomenclatures utilisées. Les grands enjeux à prendre en compte en vue d'une analyse intégrée sont présentés : les nomenclatures d'emplois utilisées pour encoder les données et le choix du niveau de détail des données pour l'analyse. Un modèle de données qui intègre toutes ces sources pour l'analyse de la polyexposition est proposé. Il s'appuie sur l'hypothèse qu'un groupe de travailleurs de même sexe, exerçant le même métier dans le même secteur d'activités est susceptible d'être exposé aux mêmes dangers et d'être atteint par les mêmes pathologies. Le secteur de la construction a été choisi pour présenter des exemples de résultats concrets : des décomptes des expositions, des co-expositions et des pathologies.
Résultats : Si on colligeait l'intégralité des bases de données, le résultat pourrait apporter des informations à propos de plus de 25 000 groupes professionnels et plus de 250 expositions, 27 000 couples d'expositions et 500 pathologies professionnelles. Dans le secteur de la construction, 92 expositions, 3508 couples d'expositions et 218 pathologies sont identifiées.

Discussion : Ces résultats préliminaires montrent la complémentarité des bases de données et décrivent comment l'hétérogénéité des données qu'elles contiennent peut-être exploitée pour apporter des connaissances supplémentaires sur la polyexposition. Ils illustrent également l'ampleur de la problématique de l'évaluation de la polyexposition à partir de ces données. La principale difficulté rencontrée est la diversité des nomenclatures métier utilisées, ce qui rend complexe leur intégration. Les suites de ce travail consisteront à identifier les analyses statistiques appropriées et à les appliquer sur les données intégrées.
https://doi.org/10.1016/j.admp.2026.103039

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1.1. Exposome

Slama, R., Siroux, V., Vrijheid, M., Basagana, X.
Relevance and challenges of exposome studies for environmental health research.
Environmental health : a global access science source, 2026, Vol 25., article 49.

The exposome encompasses all environmental exposures humans undergo from conception. We frame exposome studies according to four broad aims essential for environmental health research. First, a descriptive aim, consisting in assessing exposure patterns, including correlations between exposures and their within-subject variability. This descriptive aim includes "environmental justice" studies of associations between the exposome and sociodemographic factors. A second - etiologic - aim is to describe the subclinical and clinical effects of the exposome (hazard identification). A third aim is the quantification of the exposome health impact (e.g., in life years lost at the population level) and the ranking of exposures in terms of population disease burden (exposome disease burden or risk assessment). A fourth (intervention) aim corresponds to the identification of approaches to modify the exposome, as a way to improve health. With the large increase in the number of chemicals quantifiable in a small volume of a biospecimen, the main challenge of descriptive exposome studies is population representativeness. Regarding the etiologic aim, by simultaneously showing associations of a given biological parameter with hundreds of exposures, exposome studies effectively limit publication bias and selective reporting of results, which are a strong concern in single-exposure studies. They nonetheless face several challenges, related to the curse of dimensionality, the correlation between exposures, the breadth vs. depth tension Increasing the number of exposures considered implies to simultaneously increase study population sizes, aiming for cohorts of 100,000 subjects or more. The accuracy of exposure assessment should simultaneously be improved, e.g., by collecting repeated biospecimens within each subject, assessing exposures at various ages and decreasing limits of quantification. Classical exposome statistical designs such as ExWAS (exposome-wide association studies) are subject to a high false positive rate. Models adapted to sparse data allowing to control for confounding by co-exposures appear more efficient. The results from exposome descriptive and etiologic studies can be combined to feed exposome disease burden assessments. These can in turn help prioritize exposures for which efficient interventions need to be identified. The approaches outlined in this work could help exposome research contribute more strongly to environmental health research and to the associated risk management decisions.
https://doi.org/10.1186/s12940-026-01299-3

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Haddad, N., Lequy, E., Zins, M., Goldberg, M., Makris, K. C.
Methodological advances in designing a longitudinal urban exposome study : the UrbanX exposome study for the city of Paris within the CONSTANCES cohort.
Exposome, Vol. 6 (1), (2026), osaf019.

The complexity of urban ecosystems and populations presents major challenges in studying how urban settings shape populations' wellbeing and health over space and time. The urban exposome methodological framework has been earlier defined as the continuous spatiotemporal monitoring of population indicators

associated with urban external and internal exposome domains, using small area-level analysis. We present the design of a novel urban exposome methodological framework and outline the application of its exposomics tools as nested within a specific longitudinal setting, that is that of the CONSTANCES cohort in France.
Methods : CONSTANCES is a population-based cohort including >200 000 volunteers recruited between 2012 and 2020 and followed-up to date annually with a medical examination every 4 years. The urban Paris population and its setting is considered here, using IRIS small area level (IRIS division of the territory typically involves a population of 1800 to 5000 inhabitants). Using the human exposome domains' classification, we describe a novel methodological approach for tackling the spatiotemporal profile dynamics of the urban Paris exposome and investigate its prospective association with a health outcome, that is body mass index (BMI). Participants from the inclusion dataset are clustered into exposome-based spatial networks using hierarchical clustering on principal components, applying spatial constraints. Mixture effects of co-occurring and space- and time-varying exposome variables in their prospective association with BMI may be estimated using Bayesian kernel machine regression—lagged distribution models, random forest and/or penalized regression models.
Discussion : The application of an urban exposome methodological framework nested within a longitudinal cohort population presents with opportunities to advance our understanding of chronic disease process in complex urban settings. Advanced biostatistical algorithms that account for repeated measures of exposures and outcomes are warranted. This approach would be also applicable in multiple urban population studies nested within different cohorts.
https://doi.org/10.1093/exposome/osaf019

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Domingo, J. L., Nadal, M.
Mixture Toxicity in Human Health : Integrating One Health, Exposomics, and Modern Risk Assessment Strategies.
Chem Res Toxicol, Vol 39 (5) (2026).

Human and environmental health are critically threatened by combined exposures to multiple chemical toxicants, including industrial chemicals, heavy metals, pesticides, endocrine-disrupting chemicals (EDCs), and per- and polyfluoroalkyl substances (PFAS). These substances interact biologically, producing additive, synergistic, or antagonistic effects that conventional single-substance risk assessments fail to predict. This leads to a systematic underestimation of health risks, particularly for vulnerable populations.
Despite robust evidence on mixture toxicity, major regulatory frameworks such as the US Toxic Substances Control Act (TSCA) and the EU's REACH program continue to assess chemicals in isolation. This review synthesizes current science on toxicant interactions and critiques global regulatory shortcomings, underscoring the real-world consequences through case studies on PFAS, heavy metals, and pesticide mixtures. It advocates for a paradigm shift, proposing reforms that integrate emerging tools like exposomics and computational toxicology with holistic frameworks such as One Health.
We highlight pioneering regulatory efforts, including Canada's mandate for cumulative risk assessments under CEPA and the EU's development of mixture assessment factors (MAFs), as essential models for progress. Our recommendations include mandating science-based mixture assessments, harmonizing global standards, and implementing equity-driven policies to align regulations with the reality of multichemical exposures.
https://doi.org/10.1021/acs.chemrestox.5c00375

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Marano, F., Gamet-Payrastre, L., Sallendre, M., Urban-Boudjelab, S., Brochard, P.
Breastfeeding and environmental and occupational contaminants : protective measures.
[Allaitement maternel et contaminants environnementaux et professionnels : comment s'en protéger ?]
Environnement, Risques et Santé, Vol. 25 (2), (2026), 131-146

L'étude Conta-Lait de l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses), ainsi que le rapport du Haut Conseil de la santé publique (HCSP) sur l'allaitement maternel, publié en 2024, mettent en évidence la présence de contaminants dans le lait maternel, constat en accord avec les données internationales. La compréhension de la présence de ces contaminants implique de surveiller l'exposition et la contamination des femmes en âge de procréer, pendant la grossesse et pendant l'allaitement. Ces contaminants proviennent de diverses sources environnementales dont l'alimentation, l'air extérieur et intérieur, les produits cosmétiques et les produits à usage domestique, sans oublier l'exposition professionnelle. Cette revue fait le bilan des sources qui sont responsables de l'imprégnation de la population, dont celle des femmes allaitantes, et des actions et recommandations qui doivent permettre de mieux s'en protéger.
https://doi.org/10.1684/ers.2026.1914

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2. Biomonitoring, biomarqueurs

Ortiz-Robles, C. D., Paz-Sabillon, M., Barrera-Hernandez, A., Sanchez-Pena, L. D. C., Rangel-Calvillo, M. N., Del Razo, L. M.*, et al.*
Hair metal concentrations in a mother-newborn population from a polluted megacity : an indicator of prenatal metal exposure.
J Expo Sci Environ Epidemiol, Vol., (2026), p.

BACKGROUND : Essential elements, such as calcium (Ca), copper (Cu), and zinc (Zn) are critical for fetal development, while metals or metalloids, such as arsenic (As), antimony (Sb), boron (B), cadmium (Cd), mercury (Hg), lead (Pb), uranium (U), and vanadium (V) are potentially toxic metals (PTM) that interfere with vital processes. There is a need for biomonitoring essential and toxic metals during the uterine stage, and hair metal content may be a good biomarker.
OBJECTIVE : This study aimed to quantify the concentrations of 11 elements, including both essential and PTM, in hair samples of 96 newborn-mother pairs from an urban polluted area to assess fetal metal transfer.
METHODS : Essential elements and PTM were quantified by inductively coupled plasma mass spectrometry (ICP-MS) in hair samples. Relationships between maternal and child hair metal concentrations were examined using Spearman's rank correlation analysis, adjusting for potential confounding variables.
RESULTS : The mothers' hair PTM concentrations ranged from 8.0 ng/g to 7.0 microg/g in the following order: Cd <As <Sb<U <Hg<V<Pb <B, while in newborns' hair ranged from 1.0 ng/g to 10.0 microg/g as follows: U <Cd <As <V <Sb <Hg <Pb <B. Most PTM concentrations were higher in the mothers except for B and Sb. Significant positive correlations between the mothers' and newborns' hair concentrations of Hg (0.7365), As (0.6987), B (0.4980), Zn (0.3786), Pb (0.3012), U (0.2691), and Ca (0.2467) were observed. In addition, the Principal Component Analysis (PCA) performed in the mother-newborn pairs to identify possible common sources of exposure showed four principal components, which were not always similar in both groups.
SIGNIFICANCE : These results suggest that PTM are transferred to the fetus, although not all showed similar relationships with their mothers' concentrations, and that hair is a reliable biomarker for assessing prenatal metal exposure.
IMPACT STATEMENT : The importance of knowing the exposure to PTM during the intrauterine stage is critical to prevent adverse effects in newborns and in childhood, and lies in having good biomarkers of the exposure. Hair metal concentrations in newborns could be a valuable biomarker for prenatal exposure.
https://doi.org/10.1038/s41370-026-00869-4

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Dodds, J. N., Barlow, N., Joseph, K. M., Rehm, S. J., Chiu, W. A., Han, G.*, et al.*
Insights into complementary exposomic targeted analysis and suspect screening approaches : a case study examining human serum for chemicals with LC-IMS-MS.
Environ Sci Adv, Vol., 2026, (5), 1306-1315.

Although PFAS exposure is widespread in the general population, concern is heightened for individuals with unique occupational exposure scenarios. Accordingly, the PROject for Military Exposures and Toxin History Evaluation in US service members (PROMETHEUS) study is evaluating whether serum chemical exposure profiles correlate with cancer incidence in large cohorts (typically hundreds of samples per analysis) among military service members who may experience distinct occupational and environmental exposures.
Here we describe analytical workflow development and results from a pilot subset (n = 36) of human serum samples using an integrated targeted and suspect-screening LC-IMS-MS platform. Serum (50 microL) was extracted by acid-assisted protein precipitation with isotopically labeled internal standards, concentrated, and analyzed by LC coupled to an Agilent 6560 IM-QTOF. Targeted PFAS quantitation was performed using matrix-matched calibration curves and was benchmarked against NIST SRM 1957 to assess method accuracy. Across the samples, the targeted panel captured predominantly legacy PFAS as anticipated noting their prevalence in prior studies (e.g., PFOS, PFOA, 8 : 2 FTS, N-MeFOSAA, etc.). Ultra-short-chain PFAS presented class-specific analytical challenges ; trifluoromethanesulfonic acid (TFMS) was observed, whereas trifluoroacetic acid (TFA) eluted near the void volume and exhibited pronounced clustering in the ion mobility dimension, precluding reliable quantitation.
In parallel, CCS-based mobility filtering supported suspect screening against an exposomic library (approximately 1100 entries) to expand detectable chemical space beyond targeted PFAS. Suspect screening yielded 49 non-PFAS candidates meeting accurate mass and CCS agreement criteria, and correlation analysis recapitulated expected co-exposure groupings among legacy PFCAs/PFSAs and structurally related suspect analytes.
Collectively, these results establish a scalable, CCS-informed LC-IM-MS workflow for integrated targeted PFAS quantitation and exposomic suspect screening, enabling higher-powered association testing in the full set of PROMETHEUS samples and other large-scale human biomonitoring studies.
https://doi.org/10.1039/d6va00088f

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Mancini, F. R., Frénoy, P., Cano-Sancho, G., Marques, C., Ren, X., Perrrin, C.*, et al.*
Blood levels of Persistent Organic Pollutants and circulating biomarkers of systemic inflammation in French women : Evidence from the E3N-Generations cohort.
BMC Environmental Health, Vol., (2026)

Persistent organic pollutants (POPs) comprise a diverse class of chemicals characterized by environmental persistence, bioaccumulation, and potential toxicity to humans. Immune and inflammatory dysregulation has been proposed as a key pathway underlying their adverse health effects. This study aimed to investigate associations between circulating levels of multiple POPs—organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and per- and polyfluoroalkyl substances (PFAS)—and biomarkers of systemic inflammation, while accounting for complex exposure patterns.
We analyzed a cross-sectional sample of 468 women from the French E3N-Generations cohort. Concentrations of 45 POPs and four inflammatory markers (CRP, IL-8, MCP-1, TNF-α) were measured in blood collected in 1994–1999. Logistic regression models were first applied to assess associations between individual POPs and dichotomized biomarkers. Principal component analysis (PCA) was then used to derive exposure profiles, which were subsequently examined in regression models.
Several OCPs were positively associated with CRP levels, a finding corroborated by PCA-based analyses. After false discovery rate (FDR) correction, cis-heptachlor epoxide remained significantly associated with elevated CRP. In contrast, multiple PFAS were inversely associated with IL-8 concentrations, both individually and as part of a shared exposure component. Among them, PFOS showed the most robust

association after FDR correction.
Overall, these findings provide further insight into the complex links between mixed POP exposures and inflammatory processes, highlighting the importance of considering both individual compounds and exposure mixtures.
https://doi.org/10.21203/rs.3.rs-9427652/v1

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Sola-Martinez, R. A., Porras-Guillen, A., Lozano-Terol, G., Martinez-Vivancos, A., Gallego-Jara, J., Ortega, A., *et al.*
Breath Analysis by Mass Spectrometry-Based Technologies for Biomonitoring Environmental Exposures.
Applied Sciences-Basel, Vol. 15 (22), 2025. 12220.

Environmental exposures throughout the life of the subjects (exposome) could have a negative effect on their health outcomes. From this perspective, analysis of volatile organic compounds (VOCs) in human exhaled breath is emerging as a non-invasive tool to identify and check exposure to harmful agents. Breath analysis is also a helpful technique for human metabolism assessment, which allows for examining the impact of environmental exposures on organisms (biomonitoring).
In this paper, a comprehensive review has been carried out to assess the use of breath analysis by mass spectrometry-based technologies for monitoring environmental exposures. Records of the last 20 years from three databases (PubMed/Medline, Scopus, and Web of Science) have been evaluated independently by two reviewers. A total of 38 studies fulfilled the criteria for eligibility. It has been compiled information about environmental exposures that have been monitored by breath analysis using mass spectrometry-based analytical platforms, as well as the most commonly used protocols of breath sampling, analytical techniques, and statistical methods.
In addition, special emphasis has been placed on the huge range of VOCs selected as potential markers of environmental exposures. Despite the potential of breath analysis for monitoring human exposure, further research is needed to identify useful markers to establish it as a routine tool.
https://doi.org/10.3390/app152212220

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Zhang, H. L., Zhu, X. W., Tian, M., Wang, T. T., Wang, R. P., Zhang, M. T., *et al.*
Association of heavy metal mixtures with liver function biomarkers : multi-model analysis identifies cadmium as the primary driver.
Frontiers in Public Health, Vol. 14, (2026)

Background : Evidence regarding the hepatotoxic effects of co-exposure to multiple heavy metals in the general middle-aged and older adults population remains limited. This study aimed to investigate the association between heavy metal mixtures and liver function in the population of Northwest China, with key findings supported using an animal model.
Methods : We conducted a cross-sectional study involving 451 participants from the Dongdagou Xinglong cohort. Concentrations of heavy metals and liver function indices were measured. Multiple linear regression, Bayesian kernel machine regression (BKMR), weighted quantile sum (WQS), and quantile-based g-computation (Qgcomp) regression were employed to evaluate the combined effects of co-exposure to multiple heavy metals on liver function. A sub-chronic cadmium (Cd) exposure rat model was further established to validate population-based findings.
Results : Multiple linear regression analysis revealed that blood Cd was positively correlated with GGT (beta = 0.236), TBA (beta = 0.162), ALT (beta = 0.142) and AST (beta = 0.114), while negatively correlated with DBil (beta = -0.207), TBil (beta = -0.166) and IBil (beta = -0.157) (all $P < 0.05$). Similarly, other heavy metals also exhibited significant associations with liver function indicators. BKMR analysis showed that heavy metal mixture exposure was positively associated with ALT, AST, ALP, GGT, CHE, and TBA, but negatively associated with TBil, DBil, and IBil; WQS regression indicated that positive associations between the metal mixture and GGT as well as CHE; and the Qgcomp model demonstrated that the metal mixture was positively associated with ALT, GGT, and TBA, and negatively associated with TBil, DBil, and IBil. Notably, all

three statistical models consistently identified Cd as the factor associated with liver function biomarkers. Furthermore, animal experiments provided experimental evidence consistent with the human findings: Cd exposure led to elevated serum GGT and ALP levels and induced histopathological alterations in the liver. Transcriptomic sequencing suggested that hepatic lipid metabolism pathways may be involved in Cd-induced liver injury.
Conclusions : Overall, our study shows that co-exposure to heavy metals is associated with liver function biomarkers in middle-aged and older adults, with Cd identified as the predominant factor associated with liver function biomarkers.
https://doi.org/10.3389/fpubh.2026.1817191

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Palir, N., Dock, E., Engfeldt, M., Albin, M., Akerberg Krook, E., Bengtsson, M.*, et al.*
Exposure to legacy and emerging phthalates and bisphenols in recycling workers : Evidence from the GreenMetalWaste study.
Environ Res, Vol. 303 (Pt 2), (2026), 124765 p.

The transition toward a circular economy is driving rapid growth in the recycling sector, yet occupational exposure remains poorly characterized, including exposure to phthalates and bisphenols.
We conducted a human biomonitoring study among recycling workers handling e-waste, metal waste, and mixed waste in Sweden. The study included 114 exposed workers, 23 low-exposed workers, and 18 controls. Pre- and post-shift urine samples were analysed for phthalate and bisphenol metabolites using LC-MS/MS. Workers showed significantly higher post-shift urinary concentrations of phthalates (DiBP, DnBP, BBzP, and DnHP) and bisphenols (BPA and BPF) than controls; however, concentrations were generally lower in post-shift than in pre-shift samples across all exposure groups. Higher concentrations were observed among workers handling e-waste and metal waste, and among those performing extraction and, to a lesser extent, sorting and maintenance. Evidence of work-related exposure was observed for restricted legacy compounds (DEHP, DiBP, DnBP, BBzP, BPA) and newer or less-regulated substitutes (DPHP, DnHP, BPF). Correlation analyses indicated simultaneous co-exposure to multiple phthalates and bisphenols, and weak to moderate correlations with workplace dust concentrations (up to r(S) = 0.40) suggested that inhalation may partly contribute to exposure. Inadequate local exhaust ventilation was associated with higher urinary concentrations of most biomarkers and significantly higher BBzP levels.
These findings highlight the complex chemical mixtures present in recycling environments and underscore the need to control emissions at the source and to continue monitoring regulated and emerging phthalates and bisphenols to support prevention strategies for a growing recycling workforce.
https://doi.org/10.1016/j.envres.2026.124765

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Gunduzoz, M., Buyuksekerci, M., Ozakinci, O. G., Alaguney, M. E., Abusoglu, G., Iritas, S. B.*, et al.*
Toxic metal exposure and biomarkers of neurotoxic effects : A study in metal recycling workers.
Neurotoxicology, Vol. 114, (2026), 103469

BACKGROUND : Occupational exposure to toxic metals is a critical global health concern, particularly in the metal scrap recycling industry where simultaneous exposure to complex mixtures is common. Chronic exposure to these mixtures can disrupt redox homeostasis and trigger neuronal injury; however, human data on biomarkers reflecting early neural alterations in asymptomatic populations remain limited.
AIMS : This study evaluates biomarkers of neurotoxic effects in male recycling workers by measuring a comprehensive panel of neuronal and glial injury markers measure biomarkers indicative of possible neural damage associated with chronic toxic metal exposure.
METHODS : The study included 123 male subjects: 62 recycling workers employed in a metal scrap recovery facility (exposed group) and 61 healthy controls. Blood and urine concentrations of lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), manganese (Mn), cobalt (Co), iron (Fe), arsenic (As), and selenium (Se) were quantified using inductively coupled plasma mass spectrometry (ICP-MS). Serum levels of S100B, Neuron-specific enolase (NSE), Microtubule-associated protein 2 (MAP2), glial fibrillary acidic protein

(GFAP), Myelin basic protein (MBP), and Calprotectin (CALPRO) were measured by ELISA. Statistical associations were examined using correlation and multivariate regression analyses. RESULTS : Recycling workers exhibited markedly higher concentrations of Pb, Mn, Cd, Ni, Cu, Cr, Co, and Fe, alongside significantly decreased Se levels ($p < 0.001$), indicating substantial toxic metal overload and antioxidant depletion. Correspondingly, serum levels of S100B, NSE, MAP2, and GFAP were significantly elevated in the exposed group ($p < 0.001$), indicating subclinical neuronal and astroglial stress rather than established disease. Multivariate regression identified Pb, Fe, Cr, and Co as the most consistent independent predictors of biomarker alterations, with the NSE model demonstrating the highest explanatory power.
CONCLUSION : Chronic occupational exposure to toxic metal mixtures is associated with significant alterations in neuronal biomarkers indicative of possible neurotoxic damage in an asymptomatic population, reflecting preclinical neural stress rather than established disease. The inverse relationship between selenium and neuronal injury markers suggests a potential protective role, although this requires further confirmation. These findings support the use of an integrated multi-biomarker approach as a sensitive early warning tool for monitoring neurotoxic risks in industrial populations.
https://doi.org/10.1016/j.neuro.2026.103469

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Catalan, J., Afanou, A. K., Arranz, J. A., Riaza, A. B., Banic, I., Dirven, H.*, et al.*
An integrated approach to assess exposure and early health effects in human populations exposed to micro- and nanoplastics.
Nanoimpact, Vol. 40, (2025) Article: 100600

Although cumulative evidence from in vitro and in vivo studies indicates that micro-and nanoplastics (MNPs) can induce toxic effects, and MNPs have been detected in several human fluids and tissues, the consequences of MNP exposure to human health still remain unknown.
Human biomonitoring (HBM) studies allow assessing human exposure to MPs and associated adverse health effects, contributing to the risk assessment of these environmental pollutants. To date, reliable human exposure estimates are hindered by the lack of standardized processing and analytical methods to detect MNPs in human tissues, and limited evidence on the MNP-related adverse health effects exists. Occupational environments, where plastics are processed, may represent prioritized settings for such evaluations, as workers typically face higher exposure levels than the general population. Population sub-groups with potentially higher susceptibility, such as children and pregnant women, should also be considered. To develop effective preventive strategies, it is essential to identify and validate sensitive and specific biomarkers of exposure and early biological changes, which could result in adverse health effects. Standardized protocols integrating environmental exposure assessment with HBM, and sensitive methods for evaluating internal dose resulting from cumulative exposure to MNP particles and associated chemicals are needed. Based on the experience gathered by a multidisciplinary panel of experts belonging to the European Research Cluster to Understand the Health Impacts of MNPs (CUSP), this consensus paper describes the key elements that should be part of an integrated HBM approach for MNP exposure, emphasizing existing challenges and proposing solutions for future studies.
https://doi.org/10.1016/j.impact.2025.100600

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SCHNEIDER E. ; SANCHEZ JIMENEZ A. ; BRUN E.

Guidance for the health surveillance and biomonitoring of workers exposed to lead and its compounds.
(Orientations pour la surveillance de la santé et la biosurveillance des travailleurs exposés au plomb et à ses composés).

European Agency for Safety and Health at Work (EU-OSHA), Bilbao (Espagne), 2026, 25 p., ill., bibliogr. (En anglais)

Cette annexe au guide publié par l'EU-OSHA "Surveillance biologique au travail : orientations à l'intention des experts en SST et des lieux de travail" (notice : 745849) en 2025 fournit des orientations pratiques concernant la surveillance de la santé et la biosurveillance des travailleurs exposés au plomb et à ses

composés inorganiques. Elle explique les exigences réglementaires prévues par la directive 2004/37/CE en matière de valeurs limites biologiques pour le plomb et décrit les pratiques recommandées pour surveiller le plomb dans le sang et assurer la surveillance médicale.

Référence INRS-Biblio : 769742

Lien vers l'article : https://osha.europa.eu/fr/publications/guidance-health-surveillance-and-biomonitoring-workers-exposed-lead-and-its-compounds

Site de l'éditeur : https://osha.europa.eu

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3. Approches métabolomiques

Ji, X., Shear, M., Abrahamsson, D., Edwards, J., Wang, M., Robinson, J. F.*, et al.*
Application of non-targeted analysis for the identification of novel environmental contaminants in amniotic fluid.
Journal of exposure science & environmental epidemiology, 2026.

BACKGROUND : Amniotic fluid (AF) provides a direct window into the prenatal exposome, yet it remains understudied despite the heightened vulnerability of the developing fetus to chemical and biological perturbations. Characterizing both endogenous metabolites and exogenous contaminants in AF is essential for understanding fetal chemical exposures.
OBJECTIVE : To profile endogenous and exogenous chemical features in second-trimester AF and assess potential interactions between environmental contaminants and fetal metabolic pathways.
METHODS : Non-targeted analysis (NTA) using liquid chromatography-high-resolution mass spectrometry (LC-HRMS) was applied to AF samples (n=40) collected from participants in the San Francisco Bay Area. Compound annotation involved library matching and evaluation of diagnostic fragments. Correlation network analysis was performed to identify associations between exogenous chemicals and endogenous metabolites. Kendrick mass defect (KMD) analysis was used to distinguish chemical classes and prioritize unknown features for structural interpretation.
RESULTS : A total of 290 compounds were annotated, including ten confirmed environmental contaminants. Nine of these ten contaminants, i.e., 1,3-diphenylguanidine, N,N-dimethyltetradecylamine-N-oxide, quinoline, phthalic anhydride, acetyl tributyl citrate, 4-hydroxybenzenesulfonic acid, lauryl sulfate, 4-dodecylbenzenesulfonic acid, and dibutyl adipate, are reported in AF for the first time. These chemicals spanned surfactants, plasticizers, and industrial intermediates, indicating diverse anthropogenic sources. Correlation analysis revealed links between several contaminants (e.g., tetradecyl sulfate, phthalic anhydride, quinoline) and endogenous lipid metabolites, suggesting possible metabolic disruption. KMD analysis further differentiated chemical classes and showed that many unknown features exhibited KMD signatures consistent with exogenous esters and amine/amide-containing compounds.
SIGNIFICANCE: This study demonstrates the power of NTA to reveal previously undocumented prenatal exposures and uncover potential interactions between environmental chemicals and fetal metabolic processes. These findings expand our understanding of the prenatal exposome and highlight the need for continued investigation into environmental influences on fetal health.
IMPACT: This study presents the first application of LC-HRMS non-targeted analysis to human amniotic fluid, uncovering nine environmental contaminants that have never previously been reported in this matrix. These newly detected surfactants, plasticizers, and industrial chemicals reveal a wider range of fetal exposures than currently recognized. By expanding the chemical landscape of the prenatal environment, this work highlights the importance of NTA for discovering emerging contaminants and underscores the need to evaluate their potential impacts on fetal development.
https://doi.org/10.1038/s41370-026-00898-z

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Fernandes, C., Singh, K. S., Tilvi, S.
Metabolomics for Understanding Heavy Metal Stress Responses in Marine Organisms : A Comprehensive Review.
Current Analytical Chemistry. In Press. Available online May 07, 2026

Heavy metal pollution from anthropogenic activities poses a threat to marine ecosystems, causing complex, often sub-lethal biochemical disturbances in aquatic organisms. Studies using traditional toxicological assessments mainly offer limited insight into the underlying mechanisms of metal-induced stress. While metabolomics, in particular Nuclear Magnetic Resonance (NMR) and Mass Spectrometry (MS) based studies, has emerged as an important tool in investigating organism-level responses at a systems biology level.
This review has made effort in compiling current metabolomic research on the impacts of heavy metals, that includes cadmium (Cd), mercury (Hg), copper (Cu), zinc (Zn), arsenic (As), and silver (Ag), on marine model organisms such as the Manila clam (Ruditapes philippinarum), green mussel (Perna viridis), Mediterranean mussel (Mytilus galloprovincialis), oyster (Crassostrea hongkongensis), various fish species, and crustaceans. It is observed that there are consistent metabolic disruptions in pathways related to energy metabolism (e.g., ATP, succinate), osmoregulation (e.g., taurine, betaine), and amino acid balance (e.g., branched-chain amino acids, glutamate).
The metabolic responses were mainly tissue-specific and depended on life stage and environmental variables, such as salinity or co-exposure to other pollutants. Altogether, metabolomics provides sensitive, early biomarkers of heavy metal stress. This can contribute to a deeper understanding of ecological risk assessment and to develop more effective marine conservation strategies.
https://doi.org/10.2174/0115734110437488260223061810

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4. Modèles, outils

Belova, L., Gys, C., Kajtazi, A., Poma, G., Covaci, A.
At the Exposome's Frontier : Mass Spectrometry to Bridge the Gap between Exposure and Biological Mechanisms.
Environ. Sci. Technol. 2026, 60, (18), 13241–13244

The exposome is defined as the sum of all environmental influences and associated biological responses throughout an individual’s life course. As lifespan increases, the potential effects of the exposome are amplified, making the identification of environmental drivers of diseases critical for greater longevity.
While substantial progress has been made in characterizing chemical exposures in humans, exposomic studies often do not adequately integrate approaches that simultaneously capture the biological effects of these exposures, despite the central importance of such responses in the exposome concept. As a result, the health impact of environmental exposures remains incompletely understood, limiting the effective incorporation of exposome research into preventive medicine. In light of the holistic definition of the exposome, we highlight here several critical gaps and actionable approaches for the integration of -omics in exposome studies and the implementation of exposome data into preventive medicine, risk assessment, and policy in environmental health.
https://doi.org/10.1021/acs.est.6c02654

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La Rocca, B., Coates, L., Bourgkard, E., Ndaw, S., Malard, S., Sponne, I.
MiXie France, outil d'aide pour la prévention des polyexpositions.
Archives des Maladies Professionnelles et de l'Environnement, Vol. 87 (3-4), (2026)

En milieu professionnel, les travailleurs peuvent être exposés simultanément, ou successivement, à plusieurs substances chimiques susceptibles d'être présentes de manière concomitante dans l'organisme. Dans de telles situations, la toxicité du mélange peut être différente de la toxicité de chaque substance prise individuellement. Il apparaît donc essentiel de considérer ces polyexpositions dans la démarche de prévention. C'est d'ailleurs une obligation réglementaire, la loi « Santé au travail » imposant aujourd'hui la prise en compte des effets combinés des polyexpositions dans l'évaluation des risques. Pourtant, la plupart des méthodes conventionnellement employées pour évaluer le risque chimique repose sur une démarche qui ne tient pas compte des interactions possibles entre les substances d'un mélange. Certaines situations à risques peuvent alors passer inaperçues ou être sous-estimées. C'est dans cette optique que l'INRS a développé des méthodes et des outils tel que MiXie France, capable de prendre en compte l'exposition à plusieurs substances chimiques. [Abstract tronqué]
https://doi.org/10.1016/j.admp.2026.103665

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Liu, M., Chen, X., Ma, X., Zhang, M., Xu, X., Luo, Z.*, et al.*
Development and validation of an Occupational Hazards Index (OHI) and its association with hypertension-diabetes comorbidity in steel workers : a prospective cohort study.
BMC Public Health, Vol., (2026), 26, 1636.

[Abstract traduit] Contexte : Les ouvriers sidérurgistes sont exposés à des risques professionnels complexes ; cependant, les preuves concernant les effets conjoints de ces dangers sur la comorbidité hypertension-diabète (HDC) restent limitées en raison de l'absence d'un outil complet d'évaluation de l'exposition.
Méthodes : Une étude de cohorte prospective a été menée à partir de données de la « Cohorte sur l'effet sur la santé des populations professionnelles dans la région Beijing-Tianjin-Hebei ». Un total de 5 310 ouvriers sidérurgistes sans HDC au départ (2017) ont été suivis jusqu'en 2024. L'Indice des Risques Professionnels (OHI) a été élaboré en intégrant des niveaux mesurés de 22 dangers physiques et chimiques (par exemple, haute température, bruit, poussière, monoxyde de carbone [CO], métaux) à l'aide du modèle de norme euclidienne, basé sur les quotients de risque (concentration mesurée/Limite d'exposition professionnelle [OEL]). La HDC a été définie comme la cooccurrence de l'hypertension et du diabète de type 2. Des modèles de risques proportionnels de Cox ont été utilisés pour estimer les rapports de risques (HR) et les intervalles de confiance (IC) à 95 % pour l'association entre l'OHI (analysé à la fois comme une variable continue et catégorisé en groupes à risque élevé/faible sur la base d'une valeur de coupure limitée dérivée de spline cubique de 102,75) et le risque HDC, avec un ajustement pour les facteurs de confusion potentiels.
Résultats : Sur une période de suivi médiane de 72 mois, 595 cas incidents de CDH ont été identifiés, avec une incidence cumulative de 11,2 %. L'OHI montrait une distribution asymétrique à droite (médiane : 102,76 ; plage interquartile [IQR] : 79,38-132,38). Une relation dose-réponse non linéaire significative a été observée entre le risque d'IHO et de CDH (P pour l'association globale < 0,001, P pour la non-linéarité < 0,001). Après ajustement complet pour les caractéristiques démographiques, les antécédents familiaux de maladies chroniques, les facteurs de mode de vie, les mesures anthropométriques et les facteurs professionnels, chaque augmentation d'une unité de l'OHI était associée à un risque de HCD supérieur de 0,3 % (HR = 1,003 ; IC à 95 % : 1,001-1,005). Les travailleurs du groupe à haut risque OHI (> = 102,75) présentaient un risque 30,8 % plus élevé de HDC que ceux du groupe à faible risque (HR = 1,308, IC 95 % : 1,108-1,543). Des analyses stratifiées ont suggéré que l'association pourrait être plus marquée chez les hommes, les individus âgés de 40 à 49 ans, les fumeurs actuels et ceux ayant des modes de vie malsains (par exemple, mauvaise alimentation, obésité).
Conclusion : Nous avons développé un nouvel Indice des Risques Professionnels (OHI) qui quantifie efficacement l'exposition professionnelle combinée. Nos résultats prospectifs indiquent que des scores OHI plus élevés sont significativement associés à un risque accru de CDH chez les ouvriers de l'acier, soulignant l'importance d'une évaluation complète des risques professionnels pour la prévention primaire de cette

comorbidité.
https://doi.org/10.1186/s12889-026-27229-z

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5. Co-expositions aux métaux lourds

Hong, S. R., Wang, C. M., Yu, Z. R., Guan, X., Zhou, Y. H., Chen, S. L., *et al.*
Biological aging mediates the associations of metals exposure and cognitive function : Results from a large population-based study in China.
Journal of Hazardous Materials, Vol. 508, (2026), p.

Biological aging may be a key pathway linking environmental exposures to cognitive decline, but it remains poorly understood. The study aimed to explore the effects of multiple metals co-exposure on biological aging and the mediating effects of biological aging on the metal-cognition associations.
Among 5979 Chinese adults aged >= 50 years, we estimated biological aging by using two validated indices: KDM-accel (based on the Klemera and Doubal method) and physiological dysregulation (PD, derived via Mahalanobis distance). We measured their plasma concentrations of 23 metals and assessed their cognitive function by using Mini-Mental State Examination (MMSE).
The results showed that accelerated biological aging was significantly associated with lower MMSE score [KDM-accel: beta (95% CI) = -0.194 (-0.279, -0.109); PD: -0.180 (-0.258, -0.102)]. The plasma levels of iron (Fe) and zinc (Zn) showed inverse associations with both KDM-accel and PD, while strontium (Sr) showed a positive association with both indices (all FDR < 0.05). Compared to high Zn group, a stronger positive association between Sr and KDM-accel was observed in the low Zn group [beta (95% CI) = 0.494 (0.128, 0.860) vs. 1.453 (1.083, 1.823), P-int < 0.001]. Mediation analysis indicated that KDM-accel and PD may account for 5.51% and 15.65% of the Fe-cognition association, as well as 7.16% and 12.92% of the Zn-cognition association, which suggested potential indirect pathways.
This study identified the effects of Fe, Sr, Zn, and their co-exposure on biological aging, and suggested that biological aging deceleration may partially explain the associations of Fe and Zn with better cognition.
https://doi.org/10.1016/j.jhazmat.2026.141914

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Xiang, J. Y., Zhang, X. L., Huesker, K., Liu, Y. N., Hocher, J. G., Chen, X., *et al.*
Maternal essential and toxic metal mixtures in late pregnancy and neonatal birth weight.
Environment International, Vol. 210, (2026), p.

Background: Prenatal exposure to toxic metals has been consistently associated with impaired fetal growth, yet pregnant individuals are simultaneously exposed to mixtures of essential and toxic metals. Evidence on how such complex metal mixtures in late pregnancy influence birth outcomes in European populations remains limited.
Methods: In a prospective study of 2,754 German mother-infant pairs, 37 metals were measured in maternal blood during late pregnancy. We used elastic net regression, restricted cubic splines, Bayesian kernel machine regression (BKMR), and quantile g-computation to evaluate individual and mixture effects on birth weight, adjusting for key sociodemographic and clinical covariates. Results: Among 2,754 mother-infant pairs (median [IQR] maternal age, 30 [26-34] years; median [IQR] birth weight, 3368.0 [3025.0-3725.0] g), mixture analyses identified manganese (Mn), cobalt (Co), cadmium (Cd), and cesium (Cs) as key metals associated with birth weight. Mn ((3 = 57.86) and Co ((3 = 30.11) were positively associated with birth weight, whereas Cd ((3 = -40.82) and Cs ((3 = -25.52) were inversely associated. Bayesian kernel machine regression revealed that higher Mn concentrations were associated with weaker negative associations of Cs and Cd with birth weight. Quantile g-computation showed that mixtures dominated by Mn and Co were associated with higher birth weight (37.34 g [95% CI, 5.64 to 69.05 g]; 44.06 g [95% CI, 12.96 to 75.15 g]), while mixtures including Cd and Cs showed nonsignificant negative associations.

Conclusion : In this large European birth cohort, fetal growth was associated with the combined effects of essential and toxic metals rather than isolated exposures. The positive associations of manganese and cobalt with birth weight were weaker in the presence of co-exposure to cadmium and cesium, highlighting the importance of mixture-oriented environmental risk assessment. Integrated public health strategies that reduce toxic metal exposure while ensuring adequate maternal micronutrient status may be relevant for optimizing birth outcomes.
https://doi.org/10.1016/j.envint.2026.110244

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Paulo, M. S., Martins, C., Riesenberger, B., Cordeiro, J., Cervantes, R., Palmont, P., *et al.*
Occupational exposure to cadmium : protocol for a scoping review.
Bmj Open, Vol. 16 (4), (2026).

Introduction : Cadmium is a metal that poses significant health risks, particularly in occupational environments where exposure can happen. The main objective of this scoping review is to review the cadmium exposure levels in the different occupational settings in the European Union (EU), considering the regulatory measures currently in place. The secondary objectives, depending on the availability of data, are (a) to identify the occupational settings where higher exposure levels occur, (b) to identify any geographical and temporal differences and trends within the EU and (c) to identify the most relevant co-exposures reported.
Methods and analysis : A scoping review will be conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews reporting guidelines. Studies reporting quantitative occupational data on cadmium exposure obtained through human biomonitoring and/or air monitoring will be included. A descriptive analysis of the findings will be performed. Ethics and dissemination This protocol for a scoping review does not require ethical approval as it is based on secondary data. The dissemination plan of the scoping review includes its publication in a scientific journal of reference, as it is expected that it will provide important knowledge to support ongoing and future occupational health interventions in the EU, at the technical and regulatory levels.
https://doi.org/10.1136/bmjopen-2025-103361

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Wu, S. Y., B.
Association between urinary trace metals and multiple health outcomes.
Science Progress, Apr-Jun ;109(2) : 368504261448301

Objective : To explore the association between trace metals and multiple health outcomes.
Methods : The cross-sectional study was from eight cycles of National Health and Nutrition Examination Survey (NHANES) from 2005 to 2020. We evaluated the relationship between 11 types of urinary trace metals and multiple health outcomes.
Results : A total of 3051 participants were included in this study. The levels of barium, cesium, molybdenum, lead, antimony, thallium were significantly reduced in women, while cobalt was increased ($p<0.01$). Except for kidney stones and sleep disorders, there were significant difference in at least one type of trace metals among the participants with or without diseases. Cadmium was the most common trace metal had significant differences. Antimony could significantly increase the risk of thyroid problem and sleep disorders in women, while cobalt and manganese were just related to the risk of arthritis in man. There was a nonlinear (L-shaped) relationship between tin and heart disease, cadmium and stroke, cadmium and emphysema respectively.
Conclusions : Urinary trace metals, particularly cadmium, are modifiable risk factors for multisystem health outcomes, with effects modulated by biological sex and metal co-exposure patterns.
https://doi.org/10.1177/00368504261448301

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Behra, P., Dutta, P., Singh, A., Nirala, S. K., Bhadauria, M.
Potential of Caffeic Acid in Combating Aluminum and Beryllium Induced Oxidative Injury in Multiorgan : Insight From Hematology, Biochemistry and Histology in Rats.
Journal of Biochemical and Molecular Toxicology, Vol. 40 (5), 2026. e70849

Metal contamination poses a significant health concern driven by industrialization, landscape modifications, and rapid urbanization. Aluminum and beryllium exposure has been associated with multiple organ dysfunction, including liver, kidney and brain. In present study investigates therapeutic effects of caffeic acid in mitigating liver, kidney and brain damage induced by combined exposure to aluminum and beryllium in female rats. Rats were assigned into five groups. Group 1 served as control. Groups 2-5 were exposed to combination of aluminum nitrate (6.5 mg/kg, i.p.) and beryllium nitrate (1 mg/kg, i.p.) daily for 4 weeks. Groups 3, 4, and 5 received oral doses of caffeic acid (10, 20, and 30 mg/kg, respectively) for 2 weeks after 2 weeks of exposure to toxicants.
After 24 h of the last treatment, animals were euthanised, followed by hematology, liver kidney and brain function tests, oxidative stress and antioxidant status in studied organs. Combined exposure to metals significantly altered hematology, liver, kidney and brain function markers. Enzymatic antioxidant defenses, including reduced glutathione, catalase, superoxide dismutase, glutathione peroxidase, glutathione reductase, glutathione Sulfur transferase, and glucose-6-phosphate dehydrogenase were compromised, whereas lipid peroxidation and cholesterol levels were significantly increased. Histological observations revealed organ injury due to toxic effects of combined exposure to aluminum and beryllium. Caffeic acid treatment exhibited a dose-dependent recovery in these parameters and restored them towards control.
These findings suggested that caffeic acid may perform therapeutic role by exerting direct and indirect antioxidant effects against combined exposure to aluminum and beryllium induced injury in multiple organs.
https://doi.org/10.1002/jbt.70849

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Okeowo, O. M., Anadu, V. E., Oyerinde, T. O., Olajide, T. S., Ovwere, I. R., Ijomone, O. K.*, et al.*
Disruptions to Hepatorenal Systems Following Combined Chronic Stress and Metal Toxicities in Rats.
Bratislava Medical Journal, Vol., (2026)

Industrialization has significantly increased human exposure to co-occurring psychological stressors and environmental toxicants, including heavy metal contamination. The combined exposures to chronic stressors and heavy metal exposures are common, but their effects on the kidney and liver are not known. Hence, this study investigates how exposure to heavy metals, manganese (Mn) and nickel (Ni), in combination with a chronic stress paradigm in the rat model, impacts the structural and functional integrity of the kidney and liver. Adult Wistar rats were divided into the control, stress-only, Mn-only, stress + Mn, Ni-only, and stress + Ni groups. The rats were treated intraperitoneally with either vehicle, Mn (25 mg/kg), or Ni (25 mg/kg) with/without a restraint stress paradigm for two weeks. Blood, liver, and kidney samples were collected after sacrifice to measure hematological parameters, perform liver and kidney function tests, perform histological examinations, and assess oxidative stress markers. Our results showed significant liver and kidney damage, evidenced by the increased alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase, bilirubin (total, direct, and indirect), urea, uric acid, and creatinine levels in all treatment groups when compared to the control. Histological examinations revealed cell degeneration and necrosis, as well as glomeruli atrophy, tubular degeneration, and parenchymal disintegration in the liver and kidney, respectively. Also, there was increased lipid peroxidation, accompanied by a concomitant decrease in endogenous antioxidants, such as superoxide dismutase, catalase, and glutathione peroxidase, in the liver and kidney. When combined, these factors lead to severe inflammation, cell degeneration, and necrosis, especially with Ni exposure. In conclusion, this study reveals that co-exposure to stress and metals exacerbated hepatorenal disruptions, likely due to worsened oxidative damage.
https://doi.org/10.1007/s44411-026-00617-y

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Dooka, B. D., Orish, C. N., Ezejiofor, A. N., Umeji, T. C., Nkpaa, K. W., Obasi, C. N., *et al.*
Amyloid beta levels and occludin depletion in low dose heavy metal mixture mediated cerebellar toxicity in Wistar rats.
Sci Rep, 2026.

Co-exposure to heavy metals can result in additive or synergistic toxicity in the brain, culminating in neurotoxicity. This study investigated the neurotoxic effects of a low-dose mixture of two toxic heavy metals-lead (Pb, 20 mg/kg) and aluminium (Al, 35 mg/kg)-and one essential metal, manganese (Mn, 0.564 mg/kg), on the cerebellum of rats.
Animals were divided into five groups (n = 5) and orally treated for 90 days as follows: Group I received normal drinking water and served as the control; Group II received a heavy metal mixture of Pb (20 mg/kg), Al (35 mg/kg), and Mn (0.564 mg/kg) body weight; Group III received Pb (20 mg/kg) alone; Group IV received Al (35 mg/kg) alone; and Group V received Mn (0.564 mg/kg) alone. Chronic exposure to heavy metals resulted in a significant ($p < 0.05$) reduction in rotarod performance compared with the control group, indicating impaired cerebellar motor function.
The low-dose heavy metal mixture significantly depressed antioxidant defences ($p < 0.05$), increased lipid peroxidation ($p < 0.05$), elevated amyloid-beta peptide levels (Abeta(1)-(4)(0) and Abeta(1)-(4)(2)) ($p < 0.05$), and markedly reduced occludin expression ($p < 0.05$) in the cerebellum relative to controls. These biochemical alterations were more pronounced in the mixture-exposed group than in animals treated with individual metals. Overall, chronic low-dose exposure to an environmentally relevant heavy metal mixture induces cerebellar neurotoxicity through enhanced amyloid-beta accumulation and downregulation of occludin, a key tight junction protein, in adult male Wistar rats.
These findings underscore the role of mixed metal exposure in amyloid-beta dysregulation, tight junction disruption, and cerebellar dysfunction.
https://doi.org/10.1038/s41598-026-42725-3

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Gunduzoz, M., Buyuksekerci, M., Ozakinci, O. G., Alaguney, M. E., Abusoglu, G., Iritas, S. B., *et al.*
Toxic metal exposure and biomarkers of neurotoxic effects : A study in metal recycling workers.
Neurotoxicology, Vol. 114, (2026), 103469.

BACKGROUND : Occupational exposure to toxic metals is a critical global health concern, particularly in the metal scrap recycling industry where simultaneous exposure to complex mixtures is common. Chronic exposure to these mixtures can disrupt redox homeostasis and trigger neuronal injury; however, human data on biomarkers reflecting early neural alterations in asymptomatic populations remain limited.
AIMS : This study evaluates biomarkers of neurotoxic effects in male recycling workers by measuring a comprehensive panel of neuronal and glial injury markers measure biomarkers indicative of possible neural damage associated with chronic toxic metal exposure.
STUDY DESIGN : Cross-sectional study
METHODS : The study included 123 male subjects : 62 recycling workers employed in a metal scrap recovery facility (exposed group) and 61 healthy controls. Blood and urine concentrations of lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), manganese (Mn), cobalt (Co), iron (Fe), arsenic (As), and selenium (Se) were quantified using inductively coupled plasma mass spectrometry (ICP-MS). Serum levels of S100B, Neuron-specific enolase (NSE), Microtubule-associated protein 2 (MAP2), glial fibrillary acidic protein (GFAP), Myelin basic protein (MBP), and Calprotectin (CALPRO) were measured by ELISA. Statistical associations were examined using correlation and multivariate regression analyses.
RESULTS : Recycling workers exhibited markedly higher concentrations of Pb, Mn, Cd, Ni, Cu, Cr, Co, and Fe, alongside significantly decreased Se levels ($p < 0.001$), indicating substantial toxic metal overload and antioxidant depletion. Correspondingly, serum levels of S100B, NSE, MAP2, and GFAP were significantly elevated in the exposed group ($p < 0.001$), indicating subclinical neuronal and astroglial stress rather than established disease. Multivariate regression identified Pb, Fe, Cr, and Co as the most consistent independent predictors of biomarker alterations, with the NSE model demonstrating the highest explanatory power.

CONCLUSION : Chronic occupational exposure to toxic metal mixtures is associated with significant alterations in neuronal biomarkers indicative of possible neurotoxic damage in an asymptomatic population, reflecting preclinical neural stress rather than established disease. The inverse relationship between selenium and neuronal injury markers suggests a potential protective role, although this requires further confirmation. These findings support the use of an integrated multi-biomarker approach as a sensitive early warning tool for monitoring neurotoxic risks in industrial populations.
https://doi.org/10.1016/j.neuro.2026.103469

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Takanezawa, Y., Suda, N., Orimo, N., Nakamura, R., Ohshiro, Y., Uraguchiz, S.*, et al.*
Synergistic toxicity of methylmercury and cadmium through NRF2 suppression and mercury retention.
Journal of Toxicological Sciences, Vol. 51 (5), (2026), 315-320.

Methylmercury (MeHg) is a potent environmental toxicant that frequently coexists with other heavy metals, raising concerns about combined toxic effects. Increasing evidence indicates that coexposure to multiple metals can lead to synergistic or greater-than-additive effects; however, the molecular mechanisms underlying such interactions remain poorly understood. Among the tested metals, only co-exposure with Cd markedly enhanced MeHg cytotoxicity.
Here, our objective was to evaluate the impact of MeHg co-exposure on cytotoxicity of various heavy metals in HeLa cells. We used cell viability assays, western blot analysis, and reverse-transcription-quantitative polymerase chain reactions to determine toxicity. Co-treatment with MeHg significantly reduced cell viability compared with that of Cd alone. Mechanistically, MeHg suppressed nuclear factor erythroid 2-related factor 2 (NRF2) expression more strongly at earlier time points than Cd alone, thereby impairing antioxidant and detoxification responses. This suppression was accompanied by increased intracellular mercury (Hg) retention, leading to enhanced cytotoxicity. Our results provide a mechanistic basis for metal-metal interactions and highlight the importance of considering co-exposure scenarios in environmental risk assessment.
https://doi.org/10.2131/jts.51.315

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Xie, M. Y., Ouyang, W. X., Cui, J., Shi, J. X., An, Q., Mai, L.
Associations of Co-exposure to Heavy Metals and Per- and Polyfluoroalkyl Substances Mixtures with Medical Indicators in Colorectal Cancer Patients.
Exposure and Health, Vol. 18 (3), (2026), article number 48.

Previous studies have investigated association between metal exposure and colorectal cancer (CRC) and mainly focus on individual heavy metal or a limited combination of heavy metals. The potential effects of heavy metal mixture, as well as the joint influence of metals and per- and polyfluoroalkyl substances (PFAS) in blood on CRC prognosis remain insufficiently understood.
The present study aims to identify the association of co-exposure to heavy metals and PFAS mixtures in blood samples from CRC patients. This cross-sectional study analyzed 309 plasma samples from CRC patients to measure 14 heavy metals and integrated serum PFAS data from a prior cohort. Copper and selenium levels in plasma exhibited a positive correlation with age and demonstrated statistically significant gender-based differences (Mann-Whitney U; $P < 0.01$). Poisson regression analysis revealed that underweight CRC patients had higher selenium exposure compared to those with a normal body mass index (95% CI: 1.67 - 1.84; $P < 0.01$). Neutrophil-to-lymphocyte ratio (NLR), metastatic lymph nodes, and the ratio of the number of metastatic lymph nodes to the total lymph nodes, were selected as outcomes for assessing the prognosis of CRC.
Single-metal analysis suggested that heavy metals (such as copper and zinc) levels may be linked to CRC prognosis, with accompanying changes in inflammatory responses (e.g., NLR), and mixed PFAS exposure further pointed to a potential role of inflammation. Co-exposure to multiple environmental pollutants could be associated with CRC prognosis, but this hypothesis requires further investigation before any causal or adverse effects can be established.

https://doi.org/10.1007/s12403-026-00785-w

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Fry, B. G., Johnstone, K., Pizzino, S.
Beyond Blast Injury : Occupational Hygiene, Safety, and Toxicology Considerations for Mixed-Metal and Energetic-Chemical Exposures to Explosive Ordnance Disposal Personnel.
Toxics, 2026, Vol. 14 (5), 379.

Explosive ordnance (EO), including AXO (abandoned explosive ordnance), IEDs (improvised explosives devices), and UXO (unexploded ordnance), are widely recognised for their blast and fragmentation hazards, but they also represent a persistent and under-addressed source of occupational chemical exposure for explosive ordnance disposal (EOD) personnel.
EOD core activities liberate mixed metals and energetic chemicals, resulting in exposures that are multi-route (inhalation of dusts and fumes, dermal loading amplified by sweat and glove occlusion, and ingestion via hand-to-mouth transfer during eating, drinking, or smoking) and multi-temporal (repeated low-dose background plus task-driven spikes), as well as chemically complex.
Clinically, this can present as syndromic overlap across acute and chronic domains, with symptoms that are easily misattributed to heat stress, dehydration, infection, or fatigue. Acute effects of concern include neurotoxic presentations (headache, dizziness, confusion, tremor, and seizure), respiratory and mucosal irritation following dust or fume events, gastrointestinal symptoms, and patterns suggestive of acute hepatic or renal stress, particularly when high-intensity tasks occur in hot environments that compound physiologic strain. Chronic outcomes relevant to repeatedly exposed EOD personnel include renal function decline, neurocognitive effects that can degrade operational decision making and safety, persistent haematologic abnormalities, and endocrine disruption signals, with long-latency risks requiring cautious interpretation given sparse longitudinal data and confounding co-exposures.
This review synthesises the current evidence base through an EOD lens and translates it into pragmatic clinical and programmatic actions: task-based exposure characterisation; tiered biomonitoring and medical surveillance aligned to operational tempo; incident-triggered assessment pathways after high-residue events; and prevention strategies that work under field constraints, including contamination control zones, hygiene enforcement, glove and respiratory protection optimisation, tool and vehicle decontamination, and measures to prevent secondary transfer and take-home exposure. The central takeaway is practical: EOD programs can reduce morbidity and improve readiness by treating explosive ordnance as a chemical mixture exposure problem, adopting mixture-aware clinical triage, and embedding surveillance and controls that match how EOD work is actually performed.
https://doi.org/10.3390/toxics14050379

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Wu, D., Cheng, Y., Wang, S., Wang, N., Zhang, D., Wang, Z.*, et al.*
Association of single and combined metal burdens with systemic immune inflammation in smelter workers : A population-based study.
Journal of trace elements in medicine and biology : organ of the Society for Minerals and Trace Elements (GMS), Vol. 96, (August 2026), 127901.

BACKGROUND : Occupational exposure to mixed heavy metals, including manganese (Mn), copper (Cu), cadmium (Cd), and lead (Pb), is a major health hazard in non-ferrous metal smelting industries. Such exposure may trigger systemic inflammatory responses, which play a key role in the development of various chronic diseases. The neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and systemic immune-inflammation index (SII) are widely recognized as sensitive biomarkers of inflammation. However, their associations with mixed heavy metal exposure remain insufficiently understood among smelting workers.
OBJECTIVE : To investigate the association between combined exposure to multiple heavy metals (including Mn, Cu, Cd, Pb, and others) and systemic immune-inflammatory markers (NLR, PLR, and SII) among smelting

workers.
METHODS : A cross-sectional study was conducted involving 1087 non-ferrous metal smelting workers. Demographic, lifestyle, and occupational data were collected via questionnaires and physical examinations. Urinary concentrations of 12 metals were quantified using inductively coupled plasma mass spectrometry (ICP-MS) and adjusted for urine dilution using specific gravity (SG). Peripheral blood samples were analyzed to determine neutrophil, lymphocyte, and platelet counts, and inflammatory markers (NLR, PLR, and SII) were subsequently calculated. To evaluate associations between mixed metal exposure and inflammatory markers, generalized linear models (GLM), weighted quantile sum (WQS) regression, and Bayesian kernel machine regression (BKMR) models were applied.
RESULTS : After adjustment for urine specific gravity, 11 of the 12 urinary metals exhibited detection rates exceeding 90%, and most metals were positively correlated with one another. The strongest correlations were observed between antimony and lead (r = 0.64), arsenic and lead (r = 0.61), arsenic and antimony (r = 0.59), indium and bismuth (r = 0.58), zinc and copper (r = 0.57), tin and antimony (r = 0.55), and copper and Cd (r = 0.53). WQS regression showed that mixed metal exposure was significantly and positively associated with the (NLR; beta = 0.100, 95% CI: 0.006-0.194, P = 0.036), (PLR; beta = 6.644, 95% CI: 1.820-11.468, P = 0.007), and (SII; beta = 46.402, 95% CI: 14.603-78.200, P = 0.004) in the overall population. In sex-stratified analyses, these associations remained statistically significant among males (NLR: beta = 0.141, 95% CI: 0.034-0.248, P = 0.010; PLR: beta = 6.392, 95% CI: 1.487-11.297, P = 0.011; SII: beta = 37.623, 95% CI: 5.430-69.816, P = 0.022), but not among females. Among male workers, the metals with the highest WQS weights were In (0.335), Cu (0.226), and Zn (0.146) for NLR; In (0.445), Mn (0.202), and Sb (0.086) for PLR; and In (0.424), Cu (0.214), and Zn (0.110) for SII. BKMR analysis indicated an increasing trend in overall effect estimates for NLR and SII with higher quantiles of mixed metal exposure in the overall population, although these associations were not statistically significant. In male workers, overall effect estimates for NLR and SII increased significantly with rising mixture quantiles, whereas PLR showed an upward trend at higher exposure quantiles without reaching statistical significance. Formal interaction analysis identified a significant sex interaction in the association between urinary copper (Cu) and SII (P for interaction = 0.039), whereas interactions for Cu with NLR and Mn with PLR were not statistically significant. Copper demonstrated nonlinear exposure-response relationships with both NLR and SII, and its single-metal effect estimates remained significantly positive across different background exposure levels. Mn also exhibited a nonlinear exposure-response relationship with PLR.
CONCLUSION : After adjustment for urine specific gravity, mixed metal exposure was positively associated with elevated systemic immune-inflammatory markers among smelting workers, with stronger and more consistent associations observed in males. Copper (Cu) showed the most stable and consistent association across all analytical models. These findings suggest that combined monitoring of urinary metal exposure and inflammatory markers may have important implications for occupational health surveillance.
https://doi.org/10.1016/j.jtemb.2026.127901

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6. Polluants, pesticides mixture

Maas, S. C. E., Baraibar, I., Lemler, L., Butjosa-Espin, M., Blanco Irazuegui, O., Tabernero, J.*, et al.*
Epigenetic fingerprints link early-onset colon and rectal cancer to pesticide exposure.
Nat Med, Vol., (2026), p.

The incidence of colorectal cancer (CRC) is rising rapidly in people younger than 50 years. Although this increase parallels shifts in lifestyle and environmental factors-collectively termed the exposome-whether these are indeed linked to the development of early-onset CRC (EOCRC) remains uninvestigated. Due to limited exposome data in most cancer cohorts, we constructed weighted methylation risk scores as proxies for exposome exposure to pinpoint specific risk factors associated with EOCRC compared to late-onset CRC (LOCRC) patients diagnosed at >/=70 years. Our analysis confirmed previously identified risk factors, including educational attainment, diet and smoking habits. Moreover, we identified exposure to the herbicide picloram as a new risk factor (adjusted P = 4.4 x 10(-4)) in the discovery cohort (31 EOCRC versus 100 LOCRC), which was replicated in a meta-analysis comprising nine CRC cohorts (P = 3.1 x 10(-3); adjusted P = 1.5 x 10(-2); 83 EOCRC versus 272 LOCRC). Subsequently, we

analyzed population-based data from 94 US counties over 21 years and validated the association between picloram use and EOCRC incidence (P = 4.52 x 10(-4)), which remained significant after adjusting for socioeconomic factors and other pesticide use. These findings highlight the critical role of the exposome in EOCRC risk, underscoring the urgency for targeted personal and policy-level interventions.
https://doi.org/10.1038/s41591-026-04342-5

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Mancini, F. R., Frénoy, P., Cano-Sancho, G., Marques, C., Ren, X., Perrrin, C.*, et al.*
Blood levels of Persistent Organic Pollutants and circulating biomarkers of systemic inflammation in French women : Evidence from the E3N-Generations cohort.
BMC Environmental Health 2026, Version 1. Posted 24 Apr, 2026

Persistent organic pollutants (POPs) comprise a diverse class of chemicals characterized by environmental persistence, bioaccumulation, and potential toxicity to humans. Immune and inflammatory dysregulation has been proposed as a key pathway underlying their adverse health effects. This study aimed to investigate associations between circulating levels of multiple POPs—organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and per- and polyfluoroalkyl substances (PFAS)—and biomarkers of systemic inflammation, while accounting for complex exposure patterns.
We analyzed a cross-sectional sample of 468 women from the French E3N-Generations cohort. Concentrations of 45 POPs and four inflammatory markers (CRP, IL-8, MCP-1, TNF-α) were measured in blood collected in 1994–1999. Logistic regression models were first applied to assess associations between individual POPs and dichotomized biomarkers. Principal component analysis (PCA) was then used to derive exposure profiles, which were subsequently examined in regression models.
Several OCPs were positively associated with CRP levels, a finding corroborated by PCA-based analyses. After false discovery rate (FDR) correction, cis-heptachlor epoxide remained significantly associated with elevated CRP. In contrast, multiple PFAS were inversely associated with IL-8 concentrations, both individually and as part of a shared exposure component. Among them, PFOS showed the most robust association after FDR correction.
Overall, these findings provide further insight into the complex links between mixed POP exposures and inflammatory processes, highlighting the importance of considering both individual compounds and exposure mixtures.
https://doi.org/10.21203/rs.3.rs-9427652/v1

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Zou, Q., Zhang, Q., Liu, M., Li, H., Luo, S., Li, X.*, et al.*
Metabolite profiling of organophosphate ester exposure and type 2 diabetes mellitus risk: A metabolomics study in an epidemiological setting.
Journal of Hazardous Materials, Vol. 510, 1 June 2026, 142142.

Organophosphate esters (OPEs), a class of widespread new environmental contaminants, have garnered increasing attention due to their potential adverse health effects. However, the evidence regarding the association between OPEs and T2DM remains lacking.
We conducted a case-control study, serum samples from 144 T2DM-diagnosed individuals and 144 healthy controls were analyzed for the presence of 11 OPEs. Significantly higher levels of each OPE homologue in the T2DM group were observed, with chlorinated OPEs being predominantly present in both groups. Associations between OPEs and T2DM risk were evaluated by conditional Firth logistic regression and BKMR models, suggesting that tris (2-butoxyethyl) phosphate (TBEP), tri[(2 R)-1-chloro-2-propyl] phosphate (TCPP), and tris (1,3-dichloro-2-propyl) phosphate (TDCPP) were significantly associated with higher odds of T2DM.
A comprehensive metabolomics analysis combining targeted and non-targeted approaches to obtain broad metabolic profiles of the study participants. This analysis identified 53 metabolites and 8 metabolic pathways significantly correlated with key OPEs and linked to T2DM risk. Alterations in amino acid and lipid metabolism were observed in association with OPE exposure, showing patterns consistent with insulin secretion and glucose dysregulation. LysoPEs, 1,5-AG, and polyunsaturated fatty acids exhibited patterns consistent with potential mediation between TBEP and T2DM.

Overall, our findings suggest associations between OPE exposure and T2DM risk, with metabolite profiles suggesting potential biological pathways warranting further investigation.
https://doi.org/10.1016/j.jhazmat.2026.142142

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Golosovskaia, E., Bernander, M., Cotgreave, I., Andersson, P. L.
Modelling exposure of semi-volatile organic chemicals (SVOCs) in car cabins and assessment of their relative risks.
Atmospheric Environment, Vol. 364, (2026), 121634

Semi-volatile organic substances (SVOCs) including flame retardants and plasticizers may emit from products during their life cycle and pose health risks, such as endocrine disruption and neurodevelopmental effects. Cars, as enclosed spaces with SVOC-emitting materials, can contribute significantly to human exposure, especially for toddlers and professional drivers who may have higher risk.
This study assessed exposure to a selection of SVOCs in car cabins for various scenarios, considering car cabin temperatures (25 degrees C or 60 degrees C), user physiology (adult/toddler), and time spent in cars (average user/professional driver). Scenarios included cooling dynamics in warm cars, assuming ventilation reduces cabin temperature from 60 degrees C to 25 degrees C within 5 min.
The highest total exposure dose was estimated for di-(2-propylheptyl) phthalate (DPHP) and tris(1,3-dichloroisopropyl) phosphate (TDCIPP). Inhalation and air-to-skin contact were the dominant exposure routes for compounds like 2,2 '-methylenebis (4-methyl-6-tert-butylphenol) (MBMBP), while ingestion of dust was significant for others like TDCIPP.
Data collected from the literature on levels of SVOCs in private houses, offices and childcare facilities facilitated estimation of the contribution of cars to the total dose obtained throughout the day. Although toddlers and professional drivers had similar estimated exposure doses, despite differing times spent in cars, a first-tier risk assessment showed no immediate health concerns, with hazard quotients well below 1. However, refined models and further analysis for sensitive groups remain critical for a deeper analysis of risk.
https://doi.org/10.1016/j.atmosenv.2025.121634

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Falakdin, P., Sabzevari, S., Bos, P., Van Engelen, J., Kennedy, M., Peters, S.*, et al.*
Modeling external exposure to pesticides in human populations : Developing an exposure scenario generator.
Ecotoxicology and environmental safety, Vol. 318, (2026), 120201.

Pesticides are a significant public health concern due to their widespread use. However, estimating population exposures remains challenging, given the need to integrate multiple exposure routes and scenarios.
We developed the Pesticide Exposure Scenario Simulator (PESS) to estimate pesticide exposure across diverse population groups, including agricultural workers, residents living near treated fields, and individuals exposed through diet. PESS integrates three exposure modules (i.e., occupational, environmental, and dietary) to generate comprehensive distribution estimates.
We applied PESS to assess exposure to three pesticides : endosulfan, mancozeb, and glyphosate, representing different authorization statuses, and compared the results against urinary biomonitoring data and literature sources. Occupational exposure estimates were significantly higher under low protection scenarios, ranging from 1000 to 100,000 g/kg body weight/hour, with median values between 3000 and 10,000 g/kg body weight/hour. High protection measures reduced exposure by approximately three orders of magnitude, yielding median values around 10 g/kg body weight/hour. Environmental exposure estimates near treated fields (10 m) ranged from 1E-14-0.01 g/kg body weight/hour, decreasing to 1E-14-1E-05 at 250 m, with median values between 1E-08 and 1E-07. Dietary exposure estimates for adults ranged from 1E-06-0.1 g/kg body weight/day, with median values between 1E-04 and 0.0005.
Exposure across routes was harmonized using a daily-event framework, where short-duration occupational and environmental exposures (1 h) were treated as single daily events due to rapid pesticide dissipation in the atmosphere, and thus considered equivalent to daily exposure. Dietary exposure was inherently expressed on a daily basis, ensuring consistency while preserving the event-based nature of non-dietary exposures. Protective

equipment and application rates were key determinants of occupational exposure, while environmental exposures were primarily influenced by meteorological conditions, particularly wind speed. Dietary exposures showed lower variability in exposure values in comparison with other modules, reflecting differences in pesticide residues across food categories and age groups.
These determinants are essential for accurate exposure assessments and highlight the need for integrated tools like PESS.
https://doi.org/10.1016/j.ecoenv.2026.120201

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Yang, Z., Wu, Y., Tian, F., Bao, J., Fan, Y., Huang, S.
Co-exposure to perchlorate, nitrate, thiocyanate, and per- and polyfluoroalkyl substances (PFAS) mixtures is associated with increased rheumatoid arthritis risk : a population-based cross-sectional study.
Clin Rheumatol, 8 June 2026.

BACKGROUND : Humans are concurrently exposed to a variety of environmental endocrine-disrupting chemicals (EDCs), which include such widespread substances like urinary perchlorates, nitrates, thiocyanates, and serum per- and polyfluoroalkyl substances (PFAS). The vast majority of the previous studies were devoted to individual chemicals or certain groups of chemicals, but the impact of co-exposure to mixtures of EDCs was also not thoroughly studied. The objective of this study is to identify the relationship between these EDC mixtures and prevalence of rheumatoid arthritis (RA) based on NHANES database.
METHODS : We used three types of regression models with individual chemical effects, weighted quantile sum (WQS) regression, and Bayesian kernel machine regression (BKMR) in 2005-2012 to analyze results of individuals aged >/= 20 years. Age and gender subgroup analyses were also done.
RESULTS : A total of 4219 patients were analyzed, and 215 (5.10%) of them had RA. Multivariate logistic regression demonstrated that there was a significant relationship between thiocyanate (as a continuous variable) and the prevalence of RA. The upper quartile of perchlorate, nitrate as well as thiocyanate and MPAH showed correlation with elevated prevalence of RA. The effects of specific chemicals were stronger among the older subjects and females. WQS and BKMR models showed a positive association between co-exposure to these chemicals and RA, with thiocyanate as the primary contributor. These associations were especially strong in young adults and females.
CONCLUSION : This study provides the first evidence that co-exposure to a mixture of EDCs is positively correlated with RA, with a stronger effect in young adults and females. Thiocyanate is identified as a key contributor. Limiting exposure to EDCs may be beneficial for potentially reducing RA risk.
Key Points * We assessed the association between a mixture of ten chemicals and the risk of incidence of RA. * The co-exposure of chemical mixtures were positively associated with RA by WQS and BKMR models. * Thiocyanate was the key contributor in these mixtures. * The associations were more pronounced among young adults and females.
https://doi.org/10.1007/s10067-026-08213-9

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