# Bulletin de veille
# Polyexpositions hétérogènes
# N°5 – mars 2026

Objectif : ce bulletin présente un état de littérature scientifique sur le thème des polyexpositions hétérogènes, avec trois situations de coexpositions pouvant être rencontrées en situations de travail : associations substances chimiques et agents biologiques, associations substances chimiques et charge physique de travail, associations substances chimiques et travail de nuit.

Ce bulletin périodique a pour but de prendre connaissance des différents travaux internationaux des chercheurs dans ce domaine, d'explorer les données publiées, afin de préciser les effets sur la santé des travailleurs de ces différentes combinaisons et leurs conséquences en milieu professionnel.

*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

### Exposome

➢ Septembre 2025. A partir de la cohorte Human Early Life Exposome (HELIX), l'impact des facteurs environnementaux est étudié sur la fonction immunitaire d'enfants de divers pays, dont la France : https://lesnews.ca/lifestyle/nature-air-pur-nutrition-saine-des-allies-contre-linflammation-infantile/

➢ 26 septembre 2025. Blog Elle. Pourquoi le cancer touche davantage les Millenials, (personnes nées entre 1980 et 2000), l'exposome en cause. Lien vers l'article de ELLE

➢ 13 février 2026. Annonce du Forum mondial de l'exposome 2026 : « Comment l'exposome humain débloquera une meilleure santé et une meilleure médecine ». Le forum réunit trois dirigeants du Forum mondial de l'Exposome des États-Unis et d'Europe, pour informer les délégués de la communauté scientifique mondiale sur les progrès réalisés depuis son lancement à Washington en mai 2025. https://www.eurekalert.org/news-releases/1116616

➢ 9 février 2026. Le service de santé des armées déploie en janvier 2026 **l'étude COMITEX (Cohorte MIliTaire et son EXposome)** pour recenser les risques physiques, chimiques, psycho-sociaux des sapeurs-pompiers de la ville de Paris, risques rencontrés tout au long de leur carrière professionnelle. Etude conçue par Ipsos sous forme de questionnaire auprès du personnel actif et retraité. https://allo18.fr/etude-comitex-la-sante-du-pompier-de-paris-en-question/

➢ 24 février 2026. Les scientifiques, personnes de la société civile et membres du Parlement européen lancent l'Alliance européenne de l'exposome. En savoir plus

## Multiple expositions

➢ 14 novembre 2025. Les scientifiques appellent à une meilleure régulation des cocktails chimiques en Europe. https://www.gu.se/en/news/scientists-call-on-better-regulation-for-chemical-cocktails-in-europe

➢ Anaes, novembre 2025. **Agents du nettoyage : faire évoluer leurs conditions de travail pour mieux protéger leur santé.** https://www.anses.fr/fr/content/agents-de-nettoyage

Les agents du nettoyage sont exposés à de nombreux risques pour la santé liés à la nature même du travail effectué : efforts physiques, exposition aux produits chimiques et aux agents biologiques comme des bactéries et virus. A cela s'ajoute d'autres risques plus particulièrement liés à l'organisation du travail : horaires décalés, cadences de travail, travail isolé, activité invisibilisée, etc.

➢ 13 janvier 2026. Les Echos. « Santé et environnement : sur les traces de notre exposition aux polluants ». Lien vers l'article

## Autre

➢ 2 décembre 2025. **Odissé** : le nouveau portail open data de Santé publique France au service de tous. En savoir plus. Santé publique France met à disposition un large éventail d'indicateurs de santé construits grâce à plus de 70 systèmes de surveillance qu'elle pilote et anime, aux enquêtes qu'elle réalise et à son expertise scientifique. Tous les indicateurs produits sont accessibles et disponibles sous Odissé, le nouveau portail open data de l'agence.

Portail open data de Santé publique France, thématique santé au travail

# 1. Substances chimiques et charge physique de travail

Bodin, J., Rapicault, C., Descatha, A., Fadel, M., Gilbert, F., Evanoff, B*., et al.*

**Carpal tunnel syndrome and occupational co-exposure to biomechanical factors and neurotoxic chemicals using job-exposure matrices and self-reported exposure: Findings from the Constances cohort.**

OBJECTIVE : To study the association between occupational co-exposure to biomechanical risk factors, potentially neurotoxic chemicals and carpal tunnel syndrome (CTS) in a large cohort of French workers, using two methods to estimate chemical exposure: job-exposure matrices (JEM) and self-reported exposure.

METHODS : A randomly selected sample of adults were included between 2012 and 2018 in the French cohort CONSTANCES. Self-reported CTS was assessed using the first self-administered follow-up questionnaire, sent out approximately one year after baseline. Occupational exposure to biomechanical risk factors was assessed using self-administered questionnaire completed at inclusion. Lifetime occupational exposure to chemicals was assessed using two different methods: with JEMs and with a self-administered questionnaire completed at inclusion. Multivariate logistic regression models were used to evaluate the association between co-exposure to biomechanical risk factors and chemicals and CTS, adjusted for personal and medical factors and stratified by gender.

RESULTS : For the analysis using JEM assessment, 35,941 workers (16,920 men and 19,021 women) were included: 261 men (1.5%) and 469 women (2.5%) declared having CTS at follow-up. There was an association between CTS and the co-exposure group: OR=2.37 [1.60-3.44] in men and OR=2.09 [1.55-2.77] in women, compared to the non-exposed group. For the self-reported chemicals analysis, 42,168 workers (20,877 men and 21,291 women) were included: 338 men (1.6%) and 532 women (2.5%) declared having CTS at follow-up. There was an association between CTS and the co-exposure group: OR=3.07 [2.28-4.08] in men and OR=2.68 [1.91-3.66] in women, compared to the non-exposed group.

CONCLUSIONS : The study showed an association between self- reported CTS and co-exposure to biomechanical risk factors and chemicals. This finding should be confirmed using more objective case definition of CTS, e.g. carpal tunnel release surgery.

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Chen, X., Ma, X., Zhang, M., Liu, M., Xu, X., Luo, Z.*, et al.*
**Association between comprehensive exposure to multiple occupational hazardous factors and telomere length with hypertension in male steel workers: a case-control study.**
Frontiers in public health, Vol. **14**, (2026), 1757027.

Background: Steel workers are often exposed to various occupational hazards over the long term, which may be associated with hypertension. Previous studies mainly focused on the relationship between single occupational hazard and hypertension, but the comprehensive effects of multiple occupational hazards and the potential regulation of telomere length are still unclear. This study aims to investigate the relationship between combined exposure to multiple occupational hazards and hypertension in male steel workers, and to assess whether relative telomere length (RTL) plays a mediating role in this relationship.;
Methods: A 1:1 matched case-control study was conducted, with cases and controls matched on similar age (±2 years). The study included 350 hypertensive male steel workers and 350 normotensive controls. Occupational hazards [including heat, noise, dust, carbon monoxide (CO), shift work, and occupational stress] and relative telomere length (RTL) were assessed. An occupational hazardous factors score (OHFS) was constructed using the XGBoost model and SHapley Additive exPlanations (SHAP). Conditional logistic regression and quantile regression were used to analyze the associations. Mediation analysis was performed to evaluate the potential mediating effect of RTL in the relationship between OHFS and hypertension.;
Results: The risk of hypertension among male steel workers in the higher OHFS groups (24.74~, 38.98~, and ≥56.58) was 1.81, 2.17, and 3.46 times higher than that in the lower OHFS group (< 24.74), respectively (24.74~: OR = 1.81, 95% CI: 1.14-2.86; 38.98~: OR = 2.17, 95% CI: 1.39-3.39; ≥56.58: OR = 3.46, 95% CI: 2.18-5.49). The risk of hypertension among male steel workers in the shorter RTL group was 1.45 times higher than that in the longer RTL group (OR = 1.45, 95% CI: 1.04-2.03). A significant multiplicative interaction was observed between OHFS and RTL on hypertension (P < 0.001). Mediation analysis showed a partial mediating effect of RTL on the association between OHFS and hypertension (proportion mediated: 16.67%).;
Conclusion: Among male steel workers, higher OHFS is associated with an increased risk of hypertension, and RTL plays a partial mediating role in the relationship between OHFS and hypertension. Copyright © 2026 Chen, Ma, Zhang, Liu, Xu, Luo, Wang, Wu, Xue and Li.
https://doi.org/10.3389/fpubh.2026.1757027

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Macmurdo, M. G., Maier, L. A., Balmes, J. R., Berg, E., Brigham, E., Cummings, K. J.*, et al.*
**Occupational Exposure to Ambient Air Pollution : At-Risk Worker Groups, Regulatory and Research Needs An Official American Thoracic Society Workshop Report.**
Ann Am Thorac Soc, Vol. **22** (11), (2025), 1619-1632.

Although health effects of ambient air pollution are well established in the general population, the impact of exposure in working populations remains poorly understood. Outdoor workers are disproportionately exposed to ambient air pollution, particularly with increasing wildfire smoke events and global climate change. An international interdisciplinary group of experts including worker

representation assembled to review the current state of knowledge regarding the impact of occupational air pollution exposure on worker health and develop recommendations for research and actions to evaluate, mitigate, and regulate occupational air pollution exposure.

The group identified health risks likely resulting from air pollution based on studies of the general population, noting that additional risks may be encountered from coexposures, as well as exertion increasing the work of breathing.

High-risk groups were identified, including agricultural workers, construction workers, and wildland firefighters; others working in warehouses and indoor spaces are likely at risk via ambient air pollutant infiltration. It was estimated that at least 20 million outdoor U.S. workers are exposed to air pollution at work, which limits productivity and increases absenteeism. Participants recommended using air quality to guide work modifications and adoption of the hierarchy of exposure controls as a model to reduce exposures, as used by some states and proposed by the National Institute for Occupational Safety and Health for agricultural and other outdoor workers. Existing research supports the urgent need for policies to protect workers from exposure. Research gaps remain, including medical surveillance strategies, improved technology to protect workers, and studies specifically evaluating the impacts of occupational air pollution exposure.

https://doi.org/10.1513/AnnalsATS.202509-969ST

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Morvan, G., Bodin, J., Major, M. E., Fouquet, N., Benezet, L., Bouziri, H., *et al.*
**Fréquences d'exposition aux principaux facteurs de risque biomécaniques d'usure professionnelle chez les femmes et les hommes dans la cohorte CONSTANCES.**

Introduction : Dans le cadre de la réforme des retraites de 2023 en France, un fonds pour la prévention de l'usure professionnelle (FIPU) a été créé pour limiter les expositions à trois critères : les manutentions manuelles de charges, les postures pénibles et les vibrations mécaniques. Cette étude vise à identifier les familles professionnelles les plus exposées aux trois critères du FIPU ainsi qu'à l'ajout d'un facteur de risque biomécanique supplémentaire (répétitivité).

Méthode : Les analyses sont basées sur des données transversales de la cohorte CONSTANCES (Consultants des centres d'examens de santé). Les expositions aux trois critères du FIPU et à la répétitivité ont été décrites selon les familles professionnelles (FAP).

Résultats : Les FAP les plus exposées à au moins un des trois critères du FIPU, chez les hommes, sont les ouvriers qualifiés du bâtiment (gros et second œuvre : 95,8 % et 88,1 %) et du formage de métal (86,0 %). Chez les femmes, les FAP les plus touchées sont les aides à domicile/aides ménagères (80,3 %), les aides-soignantes (79,2 %) et les assistances maternelles (77,1 %). L'ajout du facteur répétitivité augmente la proportion d'exposés, notamment chez les femmes, et fait ressortir de nouveaux métiers comparativement à ceux obtenus avec les critères du FIPU.

Discussion : Cette étude apporte un enrichissement en fournissant des données quantitatives précises sur l'exposition aux facteurs de risque biomécaniques en France, avec une différentiation selon le sexe. En ce sens, elle permet de mieux orienter les facteurs à considérer pour la prévention de l'usure professionnelle.

https://doi.org/10.3917/spub.254.0035

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Wagoner, R. S., López-Gálvez, N. I., Casarez, I. J., Canales, R. A., Beamer, P. I., Farland, L., *et al.*
**Longitudinal associations and interactions of heat and metal(loid) exposure with kidney outcomes in Mexican agricultural workers.**
Environmental Research, Vol. **285**, (2025), 122533 p.

Background: Agricultural workers perform physically demanding labor in extreme heat, increasing their risk for kidney injury. Agricultural workers are also exposed to nephrotoxic metal(loid)s, yet little research examines the combined effects of heat and metal(loid) exposure on kidney health.
Objective: This study assessed how simultaneous exposure to metal(loid)s and heat impacts acute kidney injury (AKI) and kidney function over time.
Methods: As part of a longitudinal study, we followed a cohort of male grape farmworkers near the Arizona-Sonora border (n = 77), collecting biological samples and questionnaires at two timepoints: at the beginning (i.e., baseline) and again at the end of the work season (i.e., follow-up). Physiological strain index (PSI) was estimated using inner ear temperature and heart rate. Urine samples were analyzed for metal(loid)s, specific gravity, and neutrophil gelatinase-associated lipocalin (uNGAL), while blood serum was used to calculate estimated glomerular filtration rate (eGFR). Linear mixed effect and linear regression models evaluated the impact of metal(loid)s and PSI on kidney health, incorporating interaction terms for chronic (seasonal) and acute (PSI) heat exposure.
Results: Participants averaged 29 years old, with 35 % primarily speaking an Indigenous language. Urinary arsenic (beta = 0.35, 95 %CI: 0.15, 0.55), cadmium (beta = 0.27, 95 %CI: 0.14, 0.40), and chromium (beta = 0.54, 95 % CI: 0.20, 0.88) were associated with increased uNGAL, while increased uranium was associated with reduced eGFR (beta =-2.45, 95 %CI: 4.81,-0.08). Effects were attenuated in stratified models. Interactions showed chronic heat exposure exacerbated arsenic and cadmium's effects (arsenic-uNGAL, p <0.01; cadmium-uNGAL, p = 0.02). No significant interactions were observed for acute heat stress.
Discussion: Heat may modify the impact of toxic metal(loid)s on kidney health, emphasizing the need for workplace policies that mitigate heat stress among agricultural workers.
https://doi.org/10.1016/j.envres.2025.122533

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Zhang, Y., Li, M., Du, S., Chen, Y., Li, Q., Zhang, Z., *et al.*
**Machine learning-driven analysis of occupational heat exposure and metabolic associated fatty liver disease in petrochemical workers.**
Ecotoxicol Environ Saf, Vol. **309**, (2026), 119512 p.

OBJECTIVES: This study aimed to investigate the pathogenesis of metabolic-associated fatty liver disease (MAFLD) in petrochemical workers chronically exposed to heat and industrial chemicals, using interpretable machine learning to identify synergistic risk factors.
METHODS: A nested case-control study was conducted among 1277 petrochemical workers (mean follow-up: 8.20 +/- 1.17 years). A total of 347 MAFLD cases were matched with 930 controls (1:4 ratio) by age (+/- 5 years) and gender. Demographic, occupational, and clinical data were analyzed. After Relief-F feature selection, nine machine learning algorithms, including eXtreme Gradient Boosting (XGBoost), Light Gradient Boosting Machine (LightGBM), Random Forest (RF), Adaptive Boosting (AdaBoost), Gradient Boosting Decision Tree (GBDT), Gaussian Naive Bayes (GNB), Multilayer Perceptron (MLP), Support Vector Machine (SVM), and Decision Tree (DT), were optimized for MAFLD prediction.

Model performance was rigorously evaluated using area under the receiver operating characteristic curve (AUC-ROC) analysis with DeLong's test for statistical comparison. SHAP values were used for model interpretability.

RESULTS: Multivariate analysis revealed that prolonged heat exposure (> 10 years) significantly increased the risk of MAFLD when combined with diesel (OR = 2.31, chi(2) = 9.407, P = 0.009) or polyethylene dust (OR = 2.78, chi(2) = 10.645, P = 0.005). Certain socio-demographic factors were also played a significant role: widowed/divorced workers had a 1.89-fold higher risk of MAFLD compared with their married counterparts (chi(2) = 15.756, P < 0.001), and high-income earners (> $40,000/year) showed a 4.29-fold higher prevalence (chi(2) = 129.155, P < 0.001). The XGBoost model demonstrated greater stability, achieving a training AUC of 0.919 and maintaining a validation AUC of 0.761. The relatively smaller performance decline observed in XGBoost (DeltaAUC = 0.158) reflects better robustness and resistance to overfitting than RF. Shapley value analysis revealed visceral adiposity (0.412), marital status (0.387), and heat-diesel co-exposure (0.218) as primary drivers of MAFLD risk.

CONCLUSIONS: Chronic occupational heat exposure is a significant risk factor for MAFLD among petrochemical workers, particularly when combined with chemical exposures.

https://doi.org/10.1016/j.ecoenv.2025.119512

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**Analyse des conditions de travail des agents du nettoyage et de leurs impacts sur leur santé. Avis de l'Anses. Rapport d'expertise collective.**

Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES), Maisons-Alfort, octobre 2025, pag. mult. (29 p., 387 p.), ill., bibliogr. (En français)

Ce rapport de l'Agence nationale de sécurité sanitaire (Anses) analyse les conditions de travail et leurs effets sur la santé des agents du nettoyage intervenant principalement dans des bureaux, halls d'immeubles et locaux sanitaires, en excluant les environnements à pollution spécifique (hors sanitaires), les locaux soumis aux rayonnements ionisants et les domiciles de particuliers. Ces travailleurs, en grande majorité des femmes, sont exposés à des risques multiples : contraintes physiques (manutention, postures pénibles), exposition à des agents chimiques issus des produits d'entretien (irritants, sensibilisants, cancérogènes tels que le formaldéhyde), agents biologiques, horaires atypiques et isolement professionnel. La profession présente une sinistralité élevée avec une forte fréquence d'accidents du travail, de troubles musculo-squelettiques, de maladies respiratoires et dermatologiques, et de troubles psychiques. Les conditions d'emploi précaires (temps partiel, multi-employeurs, externalisation) accentuent ces risques. L'Anses recommande de promouvoir des pratiques de nettoyage diurnes, d'adapter les locaux et les équipements, de renforcer la formation à la prévention et d'impliquer conjointement donneurs d'ordre et employeurs dans la politique de prévention.

*Référence INRS-Biblio : 749168*

Lien vers l'article : https://www.anses.fr/fr/content/agents-de-nettoyage

Site de l'éditeur : https://www.anses.fr

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MOCQUIN A.

**La mauvaise santé des agriculteurs en fin de carrière. Démasquer les effets différés d'un travail pénible.**

Connaissance de l'emploi, n° 215, novembre 2025, 4 p., ill., bibliogr. (En français)

Au sein de la population en emploi, les agriculteurs et les agricultrices déclarent une meilleure santé que les salariés (hors cadres). Ce constat peut surprendre compte tenu de leur surexposition aux pénibilités du travail. Cet article propose une analyse attentive aux effets différés du travail sur la santé et révèle, au contraire, la prévalence des troubles physiques et psychiques qui affectent la profession en fin de carrière. Il mesure l'ampleur de ces pathologies à partir des données de l'enquête Conditions de travail (Dares) et en dévoile les causes à partir d'entretiens rétrospectifs auprès d'agriculteurs âgés de 50 ans ou plus.

*Référence INRS-Biblio : 750270*

Lien vers l'article :

https://ceet.cnam.fr/publications/connaissance-de-l-emploi/la-mauvaise-sante-des-agriculteurs-en-fin-de-carriere-demasquer-les-effets-differes-d-un-travail-penible-1586504.kjsp?RH=1507626697168

Site de l'éditeur : https://ceet.cnam.fr

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# Substances chimiques et Travail à la chaleur

Li, Q., Wu, C., Li, M., Zhang, Y., Chen, Y., Du, S.*, et al.*

**Association between occupational heat exposure and early renal dysfunction among Chinese petrochemical workers : a combined machine learning and WQS modeling study.**

Frontiers in Public Health, Vol. **13**, (2025).

Objective: To investigate the association between occupational heat exposure and hyperuricemia among petrochemical workers.

Methods: We retrospectively analyzed the association between workplace heat exposure and hyperuricemia by using 10 years of occupational health examination records from 2,312 petrochemical workers in Fujian Province, China. Generalized linear models (GLMs) were employed to estimate the effects of individual exposures. Weighted quantile sum (WQS) regression model was used to evaluate the combined effects of multiple occupational exposures and to identify the relative contribution of each exposure factor. A hyperuricemia risk prediction model was developed using the LightGBM machine-learning algorithm, with feature importance assessed using SHAP (SHapley Additive exPlanations) values.

Results: Occupational heat exposure was significantly associated with an increased risk of hyperuricemia (OR = 1.68, 95% CI: 1.28-2.20). In the GLM analysis, co-exposure to heat with benzene (OR = 1.93, 95% CI 1.05-3.55), H2S (OR = 3.38, 95% CI 1.94-5.88), gasoline (OR = 2.58, 95% CI 1.49-4.48), acid anhydride (OR = 2.21, 95% CI 1.09-4.48) and CO (OR = 2.14, 95% CI 1.16-3.97) further increased the risk (all p < 0.05), suggesting synergistic effects. The WQS analysis indicated that in the mixed occupational hazards exposure, heat exposure (49.2%) contributing nearly half the effect to the overall effect. The LightGBM

machine learning model identified length of service, age, BMI, gender, and heat exposure as the main predictors of hyperuricemia. The SHAP analysis confirmed heat exposure as a key independent contributor alongside length of service.

Conclusion: Occupational heat exposure in petrochemical settings is significantly associated with hyperuricemia, suggesting potential early renal dysfunction risk. Integrating machine learning-based predictive models into workplace health surveillance may facilitate the early identification and management of high-risk workers. However, causal inference remains limited by the retrospective design and potential residual confounding, underscoring the need for prospective studies to validate and extend these findings.

https://doi.org/10.3389/fpubh.2025.1648619

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Li, M., Zhang, Y., Wu, C., Jiang, Y., Jing, L., Wu, J*., et al.*
**Co-exposure to heat and noise on workers' health: evidence from a large-scale cross-sectional surveillance study in China.**
BMC Public Health, Vol. **25** (1), (2025), 3533.

OBJECTIVES: This study aimed to investigate the synergistic effects of co-exposure to occupational heat and noise on multi-system health outcomes among Chinese workers, and to examine the mediating role of systemic inflammation, indicated by white blood cell (WBC) count.

METHODS: A cross-sectional analysis was conducted using data from the Fujian Workplace Occupational Hazards Comprehensive Surveillance Program (2020-2022), encompassing 10,275 workers from the manufacturing, petrochemical, mining, and construction industries. Multivariate logistic regression, relative excess risk due to interaction (RERI), random forest with SHAP values, and mediation analysis were used to explore interaction effects and mediating pathways.

RESULTS: Co-exposure to heat and noise in the workplace was associated with increased risks of hypertension (OR = 1.94, 95%CI:1.61-2.36; RERI = 0.26, P interaction <0.001) and abnormal ECG (OR = 1.81, 95%CI:1.48-2.12; RERI = 0.16, P interaction <0.001), indicating synergistic effects beyond individual exposures. WBC partially mediated the effects of occupational heat and noise exposure on hypertension (heat: 9.2%; noise: 7.4%; co-exposure: 15.3%), liver dysfunction (heat: 5.4%; noise: 13.2%; co-exposure: 11.5%), and abnormal ECG findings (heat: 7.0%; noise: 6.4%; co-exposure: 8.7%). Machine learning models further confirmed that interaction between heat and noise was a stronger predictor of adverse health outcomes than either exposure alone.

CONCLUSION: Co-exposure to occupational heat and noise significantly exacerbates health risks across multiple organ systems, with systemic inflammation playing a partial mediating role. These findings highlight the importance of integrated occupational hazard assessments and targeted interventions that consider multiple concurrent occupational hazards.

https://doi.org/10.1186/s12889-025-24592-1

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Li, N., Jin, M., Lan, C. X., Xu, J., Han, B., Liu, X. J*., et al.*
**Effect of Co-Exposure to Temperature and Fine Particulate Matter on Metabolomic and Immune Processes among Chinese Women of Childbearing Age.**

Environment & Health, Vol., (2026). https://doi.org/10.1021/envhealth.5c00186

Short-term exposures to temperature and fine particulate matter (PM2.5) have been associated with metabolomic perturbations. However, their combined effect on the metabolome has not been evaluated. We investigated the effect of short-term coexposure to temperature and PM2.5 on metabolomic signatures and the potential roles of serum lipids and biomarkers using a repeated-measures study among Chinese women of childbearing age.

We performed untargeted metabolomic profiling to quantify plasma metabolites. Data on temperature and PM2.5 exposures were estimated using a fused estimator. Serum lipids and biomarkers of oxidative stress and inflammation were detected. The independent and combined effects of temperature and PM2.5 were estimated using a linear mixed-effect model and quantile-based g-computation, respectively. Pathway analysis was conducted to identify perturbed metabolic pathways. Ten women provided 46 blood samples, from which 139 metabolites were quantified. Temperature and PM2.5 had independent effects on several metabolites and pathways.

The largest positive and negative combined effects were observed for benzyl sulfate [beta = 1.460, 95% confidence interval (CI): 0.438, 2.481] and chenodeoxycholic acid glycine conjugate (beta = -1.933, 95% CI: -3.473, -0.392), respectively. Co-exposure to temperature and PM2.5 perturbed four pathways, including biosynthesis of unsaturated fatty acids; phenylalanine, tyrosine and tryptophan biosynthesis; linoleic acid metabolism; and phenylalanine metabolism. The metabolomic perturbations were mainly related to oxidative stress and the inflammatory response. We observed a positive combined effect of temperature and PM2.5 on interleukin-8.

Our findings demonstrate that the metabolic mechanisms induced by temperature and PM2.5 involve oxidative stress and the inflammatory response and suggest that these metabolomic perturbations might promote an inflammatory response via release of interleukin-8.
https://doi.org/10.1021/envhealth.5c00186

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## 2. Substances chimiques et agents biologiques

Jian, Z., Jinting, Z., Wang, L., Zhenjie, Y., Jingying, L., Shuang, W*., et al.*
**Machine learning-based prediction of occupational exposure risks among oral healthcare workers.**
Front Public Health, Vol. **13**, (2026), 1713841

OBJECTIVE: This study aims to identify the key risk factors for occupational exposure among oral healthcare workers and develop a predictive model using machine learning algorithms to lay the foundation for early screening of high-risk populations and the formulation of preemptive intervention plans.
METHODS: A multicenter cross-sectional study was conducted among 367 oral healthcare workers in 27 hospitals in Tianjin, China, from January 2025 to June 2025. Data were collected via an online questionnaire, encompassing demographic information, Work Preference Inventory, Organizational Climates, resilience, and other relevant factors. Logistic regression, random forest, decision tree, and XGBoost algorithms were employed to construct predictive models. The models were evaluated based on the area under the receiver operating characteristic curve (AUC), accuracy, sensitivity, specificity, and F1 score.

RESULTS: The incidence rates of occupational exposure in the modeling and validation groups were 15.5% and 16.5%, respectively. Univariate analysis revealed significant differences between the exposed and non-exposed groups in terms of Work Preference Inventory, Organizational Climates, resilience, professional title, hospital level, age, and gender. Multivariate analysis using logistic regression indicated that Work Preference Inventory, resilience, Organizational Climates, professional title, hospital level, and gender were independent risk factors for occupational exposure. The random forest model exhibited the best predictive performance, with an AUC of 0.755, accuracy of 89.2%, sensitivity of 56.3%, specificity of 94.7%, and F1 score of 0.600.

CONCLUSION: This study successfully identified the key risk factors for occupational exposure among oral healthcare workers and developed a predictive model using the random forest algorithm. These findings can guide the development of targeted interventions to mitigate the risks of occupational exposure. Future research should focus on validating the model with larger and more diverse datasets.
https://doi.org/10.3389/fpubh.2025.1713841

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BATTAIS P. ; JACQUENET S. ; LECHENE S. ; KUNZ-IFFLI J. ; GROSJEAN J. ; MONTA N. ; MONNOYER E. ; DIEUDONNE M. ; COISCAUD A. ; MATHIOT J. ; MULLER S. ; VEITH N. ; ALONSO L. ; LOISON P. ; DZIURLA C. ; ALBERS L. ; COULAIS C. ; BATTAIS F. ; DUQUENNE P.

**Prévention des polyexpositions dans les fromageries : de nouvelles données sur l'exposition des travailleurs et les risques associés.** Communication présentée à : CFA 2025. 38e Congrès français sur les aérosols. Paris, 18-19 mars 2025.

Institut national de recherche et de sécurité (INRS), Vandoeuvre-lès-Nancy, 2025, 4 p., ill., bibliogr. (En français)

La France compte plus de 500 fromageries employant plus de 20 000 salariés. Les travailleurs de ce secteur sont susceptibles d'être exposés à des polluants biologiques et chimiques, pouvant induire des symptômes allergiques. Des prélèvements atmosphériques de microorganismes et de bioallergènes ont été réalisés au sein de plusieurs fromageries, en ambiance dans les différentes zones de travail ou en individuel. Les concentrations en $CO_2$ ont également été suivies en temps réel. Les résultats montrent des niveaux importants de polyexposition, à des postes attendus comme le frottage, mais également à d'autres comme le conditionnement/emballage.

*Référence INRS-Biblio : 748165*

Lien vers l'article : https://doi.org/10.25576/ASFERA-CFA2025-43908

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STRAUMFORS A. ; HAUGEN F. ; SKARE O. ; EDUARD W.

**Immune modulating effects of continuous bioaerosol and terpene exposure over three years among sawmill workers in Norway.** (Effets immunomodulateurs d'une exposition continue aux bioaérosols et aux terpènes pendant trois ans chez des travailleurs de scieries en Norvège).

Scandinavian Journal of Work Environment and Health, vol. 51, n° 5, septembre 2025, pp. 433-443, ill., bibliogr. (En anglais)

Cet article présente une étude longitudinale menée en Norvège auprès de travailleurs de scieries, visant à évaluer les effets d'une exposition continue sur trois ans à divers bioaérosols et terpènes présents

dans l'environnement professionnel du bois. L'équipe de recherche a analysé les concentrations d'agents comme la poussière de bois, les acides résiniques, les endotoxines, les monoterpènes ainsi que les spores et fragments fongiques, en s'appuyant sur des matrices d'exposition propres à chaque poste. L'étude inclut 450 salariés exposés régulièrement et 65 travailleurs non exposés servant de groupe témoin. Les échantillons de sang recueillis au début et à la fin de la période d'étude ont permis d'observer que, malgré des niveaux d'exposition globalement inférieurs aux seuils réglementaires, les travailleurs des scieries développaient un profil immunitaire altéré. Les taux sériques de CC-16 et de mCRP étaient légèrement plus élevés après trois ans, indiquant des signes d'inflammation chronique de bas niveau, tandis que les concentrations sériques de cytokines pro-inflammatoires telles que IL-1β, TNF-α et IL-10 étaient significativement abaissées chez les personnes exposées. Une élévation de biomarqueurs sanguins et des leucocytes, neutrophiles et lymphocytes a également été notée après trois ans, signe d'une activation immunitaire. Par conséquent, ces résultats indiquent que l'exposition continue à la poussière de bois et aux composants associés pendant trois ans, semble induire une réponse inflammatoire chronique de faible intensité chez les travailleurs des scieries. Les auteurs soulignent l'importance de mesures préventives adaptées dans le secteur du bois et la nécessité de poursuivre la surveillance des effets sanitaires de ces expositions professionnelles, afin de prévenir à long terme les pathologies inflammatoires et respiratoires associées à ce milieu particulier.
*Référence INRS-Biblio : 747852*
Lien vers l'article : https://doi.org/10.5271/sjweh.4240

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## 3. Substances chimiques et travail de nuit

Barbey, C., Weibel, L., Clerc, F.
**Coexposure of French workers to night and/or shift work and chemical substances.**
Annals of Work Exposures and Health, Vol. **70** (2), (2026), wxaf082.

Workers in various sectors can be exposed to multiple occupational hazards, including chemical substances and night or shift work. However, the health effects of such coexposures remain largely unexplored, and we lack data on the individuals concerned. This study aimed to quantify the number of French workers coexposed to chemical substances and night or shift work and provide statistical indicators for each sector and occupation.
The analysis was based on data from the 2010 and 2017 SUMER surveys, which assessed occupational exposure in a representative sample of French workers. These data were crossed with workforce estimates from the French National Statistics Institute (INSEE) to estimate the total number of workers exposed. Four groups were defined on the basis of work schedules: (i) shift work without night work, (ii) shift work with night work, (iii) permanent night work (without shift work), and (iv) day work. The prevalence of chemical exposure in these groups was compared based on descriptive statistics. Of a total of 26.8 million French workers, about 6.5 million are exposed to night and/or shift work, with a higher prevalence among men (4.2 million) than women (2.3 million). The proportion of workers who were also exposed to at least one chemical substance was significantly higher among night or shift

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workers (36% to 49%) than among day workers (26%).

The sectors most affected were healthcare, transport, construction, and manufacturing. Common chemicals included disinfectants (alcohols, quaternary ammonium compounds, and bleach), diesel exhaust, and industrial lubricants.

Our results highlight the extent of coexposure to chemical substances and night or shift work among French workers. Given the potential health risks, particularly in the healthcare and industrial sectors, preventive measures should be implemented. Future research should investigate the long-term health effects associated with these combined occupational risk factors.

https://doi.org/10.1093/annweh/wxaf082

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Bukowska-Damska, A., Jurewicz, J., Jablonska, E.
**Caffeine consumption as a potential risk factor of osteoporosis development among night shift workers : epidemiological evidences and hypothesis.**
Int J Occup Med Environ Health, Vol. **38** (5), (2025), 474-494.

Night workers have demonstrated an increased risk of bone fracture. The mechanisms underlying the observed bone changes among night workers remain unclear. They have been attributed to hormonal changes resulting from exposure to light during nighttime, sleep restrictions and disturbances in expression of circadian rhythms genes. An additional factor that may contribute to increased bone loss among night workers is the consumption of caffeinated products.

The aim of the work was to review the epidemiological evidence on the association between caffeine consumption and bone density or fracture risk and to sum up the current knowledge on the association between night shift work and osteoporosis among workers. A search of the literature was conducted in order to identify proper studies using PubMed, Scopus, Elsevier, and Springer databases.

A total of 31 articles were identified. The articles were divided to 2 groups of papers assessing the bone fracture risk and osteoporosis among caffeinated beverages drinkers (24 studies) and assessing bone strength in night shifts workers (7 studies). Findings from studies assessing the relationship between caffeine consumption and bone strength appear inconsistent. However, the results of the some presented studies highlight that high caffeine intake increases bone loss. Thus development of osteoporosis among night workers exposed to light during nighttime might be accelerated by high caffeine consumption. No epidemiological study has examined the effect of caffeine intake on the bone fracture risk among night shifts workers yet. There is a great need to better understand the etiology of osteoporosis among workers.

https://doi.org/10.13075/ijomeh.1896.02646

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Harding, B. N., Castano-Vinyals, G., Broberg, K., Albin, M., Laurell, C., Garde, A. H.*, et al.*
**Exposome project for health and occupational research night shift cohort (EPHOR-NIGHT): a unique resource to advance research on night shift work and chronic disease.**
BMJ open, Vol. **15** (12), (2025), e106090.

PURPOSE: The EPHOR-NIGHT cohort was established to investigate how night shift work influences biological pathways and chronic disease risk using a comprehensive working-life exposome approach,

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focusing on cardiometabolic, mental health, cognitive and biological ageing outcomes.

PARTICIPANT: The cohort includes 937 workers aged 20-65 years (88%female), primarily from the healthcare sector (96%) in Spain, Sweden, Denmark and the Netherlands. Participants were categorised as permanent day (39%), permanent night (35%) or rotating/other shift workers (26%). Data collection included questionnaires, daily ecological momentary assessments, wearable sensors tracking light, physical activity, heart rate and environmental exposures and biological samples (blood collected once and saliva collected during five points across the day), with harmonised protocols across countries.

FINDINGS TO DATE: From the 937 participants contributing data to the cohort, 708 had complete information from questionnaires, sensors and blood and saliva, with subsets undergoing advanced biological analyses, including genomics, targeted and genome-wide DNA methylation, telomere length and mtDNA copy number, metabolomics, transcriptomics, proteomics, hormone profiling and inflammatory biomarkers and blood metals. Many reported prevalent chronic conditions, including anxiety (27%), depression (18%) and metabolic disturbances. Night shift and rotating shift workers had greater exposure to long shifts and more scheduled rest days compared with day workers. Sleep duration and quality were poorest among permanent night shift workers.

FUTURE PLANS: A 2-year follow-up was completed in June 2025, including the collection of additional biomarker data, psychosocial work environment data and data related to female sexual and reproductive health. Findings from the EPHOR-NIGHT study aim to inform prevention strategies and occupational health policies. Data will be made available to support broader research efforts on shift work and health.

https://doi.org/10.1136/bmjopen-2025-106090


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## 4. Autres co-expositions agents physiques

### 4.1 Bruit et substances chimiques


Choosong, T., Srimeechai, S., Dindamrongkul, R., Khaimook, W.
**Impact of ototoxic agents and noise exposure on hearing loss among healthcare personnel in a medical university: a cross-sectional analytical study.**
Bmc Public Health, Vol. **25** (1), (2025).

Background Ototoxic agents, such as xylene, formaldehyde, mercury, and antineoplastic agents, are routinely used in hospitals. Studies on hearing loss (HL) among healthcare workers (HCWs) exposed to ototoxic agents and noise remain limited in Thailand. In this study, we aimed to investigate the combined effects of low-level occupational noise and ototoxic agent exposure and evaluate the prevalence of HL among HCWs.

Methods This cross-sectional analytical study was conducted at a university hospital in Thailand between December 2022 and October 2023. Ototoxic exposure was assessed using self-reported data verified by the researchers. Occupational noise exposure levels were measured using a dosimeter, and HL was evaluated using audiometry. Multiple regression analysis was performed to identify factors associated with HL. Results Of 169 participants who underwent audiometric tests, 17.2% (29/169 participants) had HL, with 20.3% (16/79 exposed) in the exposed group and 14.4% (13/90 unexposed) in the non-exposed group (p > 0.05). HCWs exposed to antineoplastic drugs and those working in the

pharmacy department demonstrated the highest mean noise levels (75.20 +/- 3.94 dBA and 77.68 +/- 3.81 dBA, respectively). Furthermore, the average number of elevated unweighted peak noise events was observed in the pharmacy (232.89 +/- 88.66 events) and emergency (230.96 +/- 60.56 events) departments. Age, sex, and obesity were significantly associated with HL.

Conclusions A high prevalence of HL was observed among HCWs despite low noise exposure levels, underscoring the substantial impact of combined exposure to occupational noise and ototoxic agents. The identification of groups that are particularly vulnerable to antineoplastic drugs, such as HCWs, guides targeted preventive measures and further research in this area.

https://doi.org/10.1186/s12889-025-25371-8

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He, Y., Ginos, B. N. R., Kerckhoffs, J., Voortman, T., Ghanbari, M., Nedelec, R., *et al.*
**Metabolic profiles of nighttime road traffic noise exposure: A multi-cohort study in the European LongITools project.**
Environmental Research, Vol. **294**, (2026), p.

Background: Traffic noise has been associated with the risk of cardiometabolic diseases. Identifying internal exposome factors, such as metabolomic biomarkers, associated with traffic noise in the general population may help clarify the pathophysiological pathways linking noise to cardiometabolic outcomes. To address this gap, we investigated the relationships between nighttime road traffic noise and systemic metabolic biomarkers.

Methods: This study included 272,229 European adults, aged 31 years and over, from the UK Biobank (UKBB), the Rotterdam Study (RS), and the Northern Finland Birth Cohort 1966 (NFBC1966). Annual average nighttime road traffic noise was linked to the individual residential address at the time of blood sampling, using national noise maps. We utilized high-throughput nuclear magnetic resonance metabolomics to profile 155 biomarkers (including lipids, lipoproteins, fatty acids, and other low-molecular-weight metabolites). In discovery analyses in UKBB, we applied linear models adjusted for age, sex, education, and fine particulate matter to identify significant biomarkers (Bonferroni $P < 0.003125$). The associated biomarkers were further assessed using multilevel random-effects meta-analysis across the UKBB, RS, and NFBC1966.

Results: From the discovery analysis, nighttime road traffic noise (>= 55 dB versus <45 dB) was associated with higher levels of 48 metabolites in the UKBB. Associations for 20 metabolites remained robust in meta-analysis and through sensitivity analyses. Noise (>= 55 dB) was associated with elevated circulating concentrations of cholesterol-related biomarkers, including lipids in esterified cholesterol-enriched lipoproteins such as lowdensity lipoprotein (LDL) and intermediate-density lipoprotein (IDL), as well as unsaturated fatty acids and membrane biomarkers. Except for two unsaturated fatty acids, these biomarkers showed a monotonic exposureresponse pattern from 50 dB onward. Conclusion: This study provides evidence that nighttime road traffic noise exposure from 50 dB upward is associated with alterations in blood cholesterol and lipid profiles in adults. This finding may clarify the association between traffic noise and cardiometabolic diseases.

https://doi.org/10.1016/j.envres.2026.123887

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Jafarimanesh, S., Ehsani, H., Shaki, F., Moosazadeh, M., Samaei, S. E.
**Investigating the Effects of Occupational Noise and Extremely Low-Frequency Electromagnetic Field Exposure on Oxidative Response in Power Plant Workers.**
Bioelectromagnetics, Vol. **46** (7), (2025), e70027.

Occupational noise and extremely low-frequency electromagnetic fields (ELF-EMF) are common in power plants and represent important risk factors that may contribute to oxidative stress. This study examined how simultaneous exposure to these hazards affects oxidative stress biomarkers in workers under real-world conditions.
Participants were assigned to one of four exposure groups: Control (C), Noise (N), ELF-EMF (E), or a combined Noise and ELF-EMF group (NE). Occupational noise and ELF-EMF exposures were measured according to ISO 9612 and IEEE Std C95.3.1, respectively. To assess oxidative stress, venous blood samples were collected from all participants, and plasma levels of malondialdehyde (MDA), glutathione (GSH), superoxide dismutase (SOD), and total antioxidant capacity (TAC) were analyzed using validated biochemical assays. The NE group showed the highest MDA levels, indicating elevated lipid peroxidation compared with controls ($p<0.001$). GSH concentrations were lower in NE relative to controls ($p<0.001$). SOD activity was significantly reduced in both the N and NE groups compared with the control group ($p<0.005$). TAC was lowest in the NE group, showing a significant decrease compared with both the control and Noise-only groups ($p<0.05$).
While these findings suggest that concurrent exposure to noise and ELF-EMF can influence oxidative stress biomarkers, they do not provide direct evidence to mandate specific workplace monitoring or interventions. Further studies are needed to clarify potential health risks and to guide evidence-based occupational safety measures.
https://doi.org/10.1002/bem.70027

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Elyasi, H., Kakavandi, M. G., Almasi, A., Seifmanesh, S., Dehkiani, F. A., Khosravipour, M.
**Differential impacts of co-exposures to ELF-EMFs and noise on prostate-specific antigen levels: A longitudinal study.**
Environmental Research, Vol. **286**, (2025), 122790 p.

Animal studies indicating an association of exposure to extremely low frequency electromagnetic fields (ELFEMFs) and noise with reproductive dysfunctions. Nonetheless, the potential impacts of exposure to these hazardous agents on the human prostate gland remain unidentified.
To assess the relationship between co-exposure to ELF-EMF and noise and the levels of prostate-specific antigen (PSA), a longitudinal study was conducted over eight years among workers at a thermal power station from 2016 to 2024.
The 8-h equivalent noise level (LAeq and LZeq; dB unit) and the 8-h average of ELF-EMFs (mG unit) were calculated to measure noise and ELF-EMF exposures, respectively. The changes in the levels of PSA were estimated by different linear regression models. In total, we examined data from 974 observations. Per 10-dB increment of LAeq, the significant increases in the logtransformed PSA levels were found in both unadjusted (Coefficient: 0.068 and 95 % CI: 0.044, 0.091) and adjusted (Coefficient: 0.040 and 95 % CI = 0.012, 0.069) models.
This association remained significant after further adjusting for ELF-EMFs (no significant effect modification for ELF-EMFs). In all regression models, no significant changes were observed in the PSA levels per unit raise in the ELF-EMFs levels. No significant interaction was found between ELF-EMFs and

noise.

In conclusion, our findings indicate that noise may affect prostate health. Additional studies are needed to investigate the mechanisms involved and to validate this connection.

https://doi.org/10.1016/j.envres.2025.122790

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## *4.2 Autres co-expositions hétérogènes*

Colin, R., Boini, S.
**Co-expositions aux facteurs de risque psychosociaux et physiques et survenue d'accidents du travail selon l'activité professionnelle.**
Archives des Maladies Professionnelles et de l'Environnement, Vol. **86** (6), (2025), 102957.

Objectifs : Identifier les facteurs psychosociaux (FPS) et les facteurs physiques déterminant la survenue d'accidents du travail (AT) selon l'activité professionnelle. Caractériser l'effet des co-expositions aux facteurs de risque physiques et aux FPS dans une approche longitudinale.

Méthodes : La population d'étude était constituée des travailleurs participant à l'enquête Conditions de Travail en 2013 et en 2016 et appartenant à cinq regroupements d'activité : « bâtiment, travaux publics, électricité » (BTPE) (n = 1158) ; « industrie, exploitation, maintenance, logistique » (IEML) (n = 2 496) ; « médico-social » (MS) (n = 3181) « services aux particuliers et collectivités » (SPC) (n = 2383) et « commerce, transport, tourisme » (CTT) (n = 1910). Les expositions aux facteurs de risque physiques et psychosociaux étaient recueillies en 2013. Les AT survenus dans les 12 derniers mois précédant le recueil de 2016 étaient auto-déclarés par les salariés.

Résultats : Globalement, l'ensemble des contraintes physiques était associé à un sur-risque d'AT avec arrêt de travail avec des IRR allant de 1,78 pour SPC à 7,02 pour BTPE en cas de cumul d'exposition à plusieurs contraintes physiques. L'ensemble des expositions aux FPS était associé à un sur-risque d'AT pour MS, SPC et CTT. Pour BTPE, seule l'exposition à une forte intensité du travail était associée à un sur-risque de survenue d'AT (IRR = 1,43). Pour IEML, le manque d'autonomie, les rapports sociaux au travail dégradés ainsi que les conflits de valeur étaient associés à un excès de risque d'AT. L'exposition conjointe à plusieurs FPS augmentait le risque de survenue d'AT pour MS (IRR = 1,50), SPC (IRR = 2,18) et CTT (IRR = 1,70). Pour BTPE et IEML, une exposition psychosociale élevée n'accroissait pas de manière significative le risque de survenue d'AT quel que soit le niveau d'exposition aux facteurs de risque physiques. Pour MS et CTT, les taux d'AT étaient significativement plus élevés pour les travailleurs exposés conjointement à une exposition physique forte et une exposition psychosociale forte par rapport à une exposition physique forte uniquement (respectivement p = 0,005 et p = 0,028). Enfin, une exposition élevée aux FPS augmentait le risque de survenue d'AT pour le groupe SPC quel que soit le niveau d'exposition aux facteurs de risque physiques (p < 0,01).

Conclusions : Les co-expositions sont de nature différente et ne produisent pas systématiquement les mêmes effets selon les activités professionnelles.

https://doi.org/10.1016/j.admp.2025.102957

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Myshchenko, I., Paluszek, K., Karpczak, D.
**Occupational noise and vibration risks for go-kart instructors in a dynamic track environment.**
Sci Rep, Vol. **15** (1), (2025), 44811.

This study evaluates occupational noise and vibration exposure among nine male go-kart instructors (mean age 25.7 years, mean work experience 6.3 years; 2-12 years) using objective measurements, predictive modelling, and subjective hearing assessments. Daily noise exposure (L(EX,8 h)) ranged from 75.8 dB to 82.3 dB, with peak levels reaching 109.3 dB. Regression analysis showed that operating more than nine go-karts simultaneously could exceed the 85 dB regulatory threshold, predicting noise levels up to 92.7 dB at full capacity. Whole-body vibration (WBV) exceeded short-term exposure limits in two of four cases (max 3.26 m/s(2)), while hand-arm vibration (HAV) surpassed limits in three cases, reaching 14.23 m/s(2). The average score on the Amsterdam Inventory for Auditory Disability and Handicap (AIADH) was 68.1, indicating mild perceived hearing difficulties. Strong negative correlations were found between AIADH scores and both age and work experience. Our findings reveal hidden risks in this recreational occupational setting and underscore the need for more nuanced exposure assessment and preventive measures in non-industrial sectors.
https://doi.org/10.1038/s41598-025-28837-2

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# 5   Exposome, impact des facteurs environnementaux sur la santé

Vogli, M., Jeong, A., Yu, Z., Vonk, J. M., Ibi, D., Kronberg, J.*, et al.*
**The impact of environmental exposures on DNA methylation in the EXPANSE project.**
EBioMedicine, Vol. **123**, (2025), 106084.

BACKGROUND: Living in an urban environment exposes the population to a mix of environmental and social factors, known as the Urban Exposome, that can influence health via changes in DNA methylation. We hypothesised that linking urban exposures with epigenome-wide DNA methylation in blood can reveal impacts across the lifespan.
METHODS: In the EXPANSE project, we conducted an inverse variance-weighted meta-analysis of epigenome-wide association studies of seven European cohorts. Urban exposures were estimated at participants' home addresses and included air pollution (PM2.5, NO2, O3), light at night, modified soil-adjusted vegetation index, and urbanicity.
FINDINGS: DNA methylation was measured in blood samples from 1778 children (4-10 years), 878 adolescents (16 years), and 5975 adults (18-87 years). PM2.5, NO2, and greenness were associated with methylation differences in children, while greenness and urbanicity showed associations in adults. Regional analyses showed differentially methylated regions (DMRs) across all life stages. Pathway analysis showed that monthly NO2 in children was linked to immune and infectious disease pathways, whereas adult urbanicity was associated with immune pathways as well as PD-L1 expression and the PD-1 checkpoint pathway in cancer.
INTERPRETATION: Urban environmental factors induce DNA methylation changes across life stages, with stronger associations in young children and adults. We observed a distinct contrast in the methylation changes associated with greenness compared to other urban environmental factors. However, disentangling exposure-specific methylome signatures remains a challenge.
FUNDING: This work was supported by the EXPANSE project, funded by the European Union's Horizon

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Sarigiannis, D., Anesti, O., Papaioannou, N., Karakoltzidis, A., Karakitsios, S.
**Computational standards and tools for exposome-wide association studies linking the human exposome with health outcomes.**
Environment international, Vol. **208**, (2026), 110117.

The human exposome (the cumulative measure of environmental exposures across the life course) offers a critical complement to genomics in deciphering the multifactorial origins of complex diseases. Exposome-wide association studies (ExWAS) represent an emerging class of high-dimensional epidemiological analyses designed to systematically assess associations between diverse environmental exposures and health outcomes. However, ExWAS requires advanced computational standards and tools capable of handling exposure complexity, temporal variability, co-exposure correlation, and multi-omics data integration. This review synthesizes current computational methodologies and platforms for ExWAS, highlighting recent advances in statistical modeling, exposure quantification, and bioinformatics tools. We conducted a PRISMA-ScR-guided scoping review across PubMed, Scopus, and Web of Science (2010-2025), with dual-reviewer screening in Rayyan, standardized data charting, and SWiM-aligned narrative synthesis. We explore multivariable and mixture modeling approaches (e.g., weighted quantile sum regression, Bayesian kernel machine regression), integration of external and internal exposome domains, and the application of longitudinal designs and environmental risk scoring. Key platforms such as the rexposome suite, exposomeShiny, and the integrative INTEGRA framework are examined for their role in operationalizing exposomic analyses at population scale. We also discuss the importance of data standardization, including exposure ontologies, harmonization protocols, and federated data infrastructure supporting cross-cohort analyses. Moreover, we discuss how computational exposomics can elucidate mechanistic pathways linking environmental exposures to disease, particularly when integrated with transcriptomic and metabolomic data. Finally, we outline future directions for the field, including genome-exposome integration, AI-driven causal inference, and translational pipelines for regulatory and clinical implementation. Beyond listing methods, we assess computational maturity and reproducibility (open licensing, containerization, federation readiness) and connect standards+tools to ExWAS workflows and translation. Computationally mature and mechanistically anchored, ExWAS are poised to become central tools in precision environmental health, enhancing the interpretability of genome-environment interactions and the predictive power of integrated omics frameworks.
https://doi.org/10.1016/j.envint.2026.110117

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Gaba, S., Lefeuvre, S., Ouedraogo, F., Mougard, C., Brillard, E., Delva, F*., et al.*
**Territory health : A transdisciplinary approach of environmental, plant, animal, and human health interdependencies in a rural landscape in France.**
Iscience, Vol. **29** (3), (2026).

Health is increasingly understood as an integrated property of human, animal, plant, and environmental systems, as articulated by the One Health and EcoHealth concepts. The Territory Health project applies these perspectives within an agricultural landscape to examine interdependencies between

environmental, nonhuman organisms, and human health. Using in a participatory and experimental approach, the project brings together researchers, local residents, farmers, decision-makers, and NGOs to investigate the relationships between pesticide use, in situ exposure to pesticide mixtures, and health effects on non-target organisms. A key objective is to establish a "partner cohort" to examine how changes in food production, dietary practices, and the human-nature relationship shape health of the territory under study. By situating the foodbiodiversity-environment-health nexus within a socio-ecosystem perspective, this work supports agrifood system transformations toward long-term territorial health.

https://doi.org/10.1016/j.isci.2026.114956

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Crepet, A., Quenel, P., Garric, J., Kaufmann, A., Bonmatin, J.-M., Duche, P.*, et al.*
**Integration of the exposome concept into health risk assessments: a challenge for health safety agencies.**
Environmental research, Vol. **286** (Pt 3), (2025), 123036.

The exposome is a concept that aims to study the environmental factors to which individuals are exposed during their lifetime and the role of these factors in the development of chronic diseases. Since the concept emerged in 2005, new data, methods, and tools have been generated by the scientific community to assess the different components of the exposome and their impacts on human health.
Currently, one of the main challenges is accounting for the diversity and complexity of exposures and their effects on health in risk assessment, which might be accomplished by integrating the exposome into this process. To this end, a working group was constituted by Anses to develop a strategy to integrate the exposome concept in risk assessment and more generally in the work produced by health safety agencies.
We present the principal challenges to be addressed by considering 8 themes covering relevant aspects of the exposome and we made recommendations for each theme: 1) characterization of the exposome in epidemiological surveys; 2) exposome data; 3) risk assessment of chemical mixtures; 4) aggregation of multiple sources and routes of exposure; 5) dynamics of the exposure in the context of time, space, and social factors; 6) establishment of reference values; 7) multiple factors in risk, benefit and health impact assessment; and 8) eco-exposome.
Then, we propose practical recommendations with short-, medium-, and long-term time scales to progressively operationalize the exposome into risk assessments implemented by health safety agencies. We also discuss how providing broader exposome input into risk assessment can support risk regulators to incorporate exposome input into risk management.
https://doi.org/10.1016/j.envres.2025.123036

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Barzilay, R., Jeste, D. V.
**Exposome and mental health across the lifespan: research and clinical perspectives.**
Neuropsychopharmacology, online 09 mars 2026

Mental health is shaped by the complex interplay of genetic and environmental factors, each contributing to individual differences in risk and resilience. While genetic influences are increasingly well-characterized, understanding the role of environment is critical for several reasons. First, environmental exposures are potentially modifiable, and if proven causal, they offer actionable targets

for interventions aimed at preventing or mitigating mental illness. Second, quantifying the environment in aggregate within biomedical research has long been challenging, largely because it requires accounting for multiple environmental components at once. As a result, previous studies have often struggled to fully assess environmental exposures and to connect overall environmental burden to health outcomes. Although this remains a complex challenge, recent advances in measurement and analytic methods provide new opportunities to more thoroughly quantify the environment and evaluate its impact on health and disease. Finally, environment is key to understanding mental health disparities, which is crucial for promoting health equity and guiding public health strategies. Focusing on environmental factors can therefore advance mental health understanding and promote more equitable prevention and care across the lifespan.

https://doi.org/10.1038/s41386-026-02333-1

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Tartaglia, M., Ge, C., Pronk, A., Costet, N., Audignon-Durand, S., Houot, M.-T.*, et al.*
**Multiple maternal occupational exposures during pregnancy and intrauterine growth: analysis of the French Longitudinal Study of Children - ELFE cohort, using data-driven approaches.**
International Journal of Hygiene and Environmental Health, Vol. **270**, (2025), 114666.

Objective: To use data-driven approaches to investigate maternal multi-occupational exposures during pregnancy and their effects on intrauterine growth.
Methods: Maternal occupational exposure to 47 factors during pregnancy was evaluated with job-exposure matrices in the French ELFE cohort. The outcomes of interest were birthweight (BW), small for gestational age (SGA) and head circumference (HC). Occupational exposures associated with these outcomes were identified by EWAS, LASSO, and random forest. The five exposures with the strongest effects selected with these approaches were included in a final multivariate model with significant interactions.
Results: We included 12,851 women. The most important occupational factors predictive of SGA were endocrine disruptors, high strain, kneeling/squatting, job demands, physical effort. No significant associations were detected when these variables were combined in a final model. For BW, the most important variables were leaning forward/sideways, using a computer screen, ultrafine particles, physical effort, airborne germs, repetitive actions. The use of a computer screen significantly decreased BW and, for women not exposed to airborne germs, leaning forward/sideways significantly increased BW. For HC, repetitive actions, oxygenated solvents, kneeling/ squatting, airborne germs, working outdoors were the most important predictive factors. Repetitive actions and working outdoors significantly decreased HC. HC also decreased in women exposed to both airborne germs, and oxygenated solvents. Similar results were found for women who worked during the third trimester.
Conclusion: Our findings highlight potential roles of chemical, biological and postural factors and their interactions in determining intrauterine growth. These results highlight the importance of considering multiple exposures in occupational health studies.

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