European Human Exposome *NETWORK*

Policy Brief

May 2025

Unravelling the exposome

Environmental factors cause multiple diseases and are fuelling a growing public health crisis. Researchers and policymakers must work together to understand and investigate the environmental drivers of diseases, and develop interventions to slow and reverse these trajectories.

The exposome concept and exposomics

The exposome is a collective term for the physical, chemical, biological and social influences on our health. This includes the environmental factors we encounter on a daily basis throughout our lives: what we eat, the air we breathe, our social interactions and lifestyle choices.

In a shift from traditional scientific research, which focuses on how single exposures affect a single disease, the emerging field of exposomics takes a holistic view.

Exposomics uses data from a range of sources to investigate the dynamics between multiple environmental exposures and health outcomes.

This policy brief presents a selection of scientific evidence, tools, and success stories from five years of European Human Exposome Network (EHEN) research. Its aim is to inform and inspire policymakers to take action to protect citizens' health from pollution and environmental deterioration.

Policy call to action

↘ Create more **urban green spaces** and walkable neighbourhoods
Urban Health **(pages 2–3)**

↘ **Tackle air and noise pollution** in economically disadvantaged European regions and urban areas.
Urban Health **(pages 2–3)**

↘ Act to protect health from **early in life**, as foetuses and children are highly vulnerable to exposures.
Urban Health **(pages 2–3)**

↘ **Strengthen regulations** on chemicals to better protect citizens' health.
Chemicals **(pages 4–5)**

↘ **Clarify laws** on broad consent and personal data – both are essential enablers of research.
Research data management **(pages 8–9)**

↘ **Invest further** in EU research infrastructures to build on EHEN's legacy of tools for exposome science.

Urban Health

Acting on scientific evidence linking the urban exposome to an increased risk of a range of non-communicable diseases (NCDs), EHEN researchers used techniques from epidemiology, environmental science, urban planning and health economics to investigate the causes of urban health issues.

Examples of EHEN's exposome approach

- **Creating high-spatial resolution exposome maps** to provide an overview of **air pollution across Europe**[1] using satellites, pollution monitoring stations, **traffic flow modelling**[2] and **neighbourhood-based mobile monitoring equipment**[3], and to research the cumulative health effects of multiple exposures, including air and noise pollution, and urban geographical features such as access and proximity to green space, walkability, socio-economic and social factors, and population density.

- **Investigating the "social exposome"** using machine learning algorithms to identify "**exposome clusters**[4]". Using this approach, researchers were able to link certain combinations of social, built and natural environmental exposures to specific health outcomes in a child cohort.
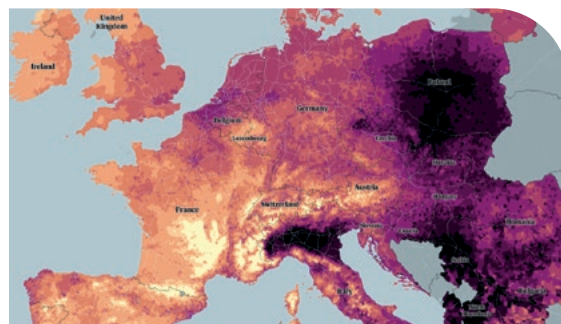

Fig. 1. European air pollution map © OpenStreetMap

- **Modelling pollution exposure in a laboratory** using **atmospheric simulation chambers**[5] to mimic actual urban air pollution events and predict effects on lung development and disease.

- **Analysing sewage water samples** from different urban areas using metagenomic deep-sequencing and microbial classification. The analysis found clear differences in microbial profiles between locations.

EHEN scientific evidence

Air pollution is a public health emergency, with **economically disadvantaged regions worst affected**[6]. Several EHEN studies show its harmful effects, starting from **prenatal exposures**[5].

Environmental noise[7] seriously affects children's mental and physical health and cognitive development. Noise pollution can be worse in socio-economically deprived urban areas due to higher traffic, and reduced protective and obsolete acoustics measures.

Several EHEN publications show that **urban biodiversity**[8 9 10] affects health, and that interventions such as **urban rewilding** can **improve immune responses**[11].

Wastewater-based epidemiology (WBE)[12] can be used to track circulating pathogens and long-term environmental exposures at a local community level.

1   Revealed: almost everyone in Europe is breathing toxic air. *The Guardian*, 20 September 2023.
2   Shen Y. et al. Europe-wide high-spatial resolution air pollution models are improved by including traffic flow estimates on all roads. *Atmospheric Environment*, Volume 335, 2024.
3   Kerckhoffs J. et al. Hyperlocal variation of nitrogen dioxide, black carbon, and ultrafine particles measured with Google Street View cars in Amsterdam and Copenhagen. *Environment International*, Volume 170, 2022.
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6   Saucy A. et al. Socioeconomic Inequalities in the External Exposome in European Cohorts: The EXPANSE Project. *Environmental Science & Technology*, 2024, 58 (37).
7   Terzakis M. et al. Noise Indicators Relating to Non-Auditory Health Effects in Children – A Systematic Literature Review. *International Journal of Environmental Research and Public Health* 2022, 19 (23).

Fig. 2. Urban intervention study (Source: HEDIMED)

Next steps for research and policy

- Study a wider range of exposures and health outcomes using a combination of **EHEN tools**[13] for policymakers including exposome maps, harmonised data from population-wide cohort studies, and laboratory simulation platforms.

- Use these tools to design **intervention studies** and measure the **cost-effectiveness**[14] of policies to improve urban health.

- Expand environmental monitoring approaches piloted by EHEN researchers.

> *Scientists need to work with policy makers on implementation— testing interventions at local levels, learning from each step, neighbourhood by neighbourhood, to demonstrate health impacts.*

Roel VERMEULEN
Principal Investigator
EXPANSE project

Policy call to action

- ⭨ Urban air pollution is a public health emergency that requires a holistic policy response – through social and climate policy as well as the traditional focus on particle emissions.

- ⭨ For new urban developments – design low noise and walkable neighbourhoods to reduce environmental stressors, and encourage physical and social activity.

- ⭨ For existing neighbourhoods, support local initiatives to create urban green spaces and improve biodiversity, and work with researchers to measure outcomes through intervention studies.

- ⭨ Expand coverage of urban noise monitoring – this is currently limited to large cities.

8   Seastedt H. et al. Impact of urban biodiversity and climate change on children's health and well-being. *Pediatric Research*, 2024.
9   Fernandes A. et al. Green spaces and respiratory, cardiometabolic, and neurodevelopmental outcomes: An individual-participant data meta-analysis of > 35 000 European children. *Environment International*, Volume 190, 2024.
10 Motoc I. et al. Examining associations of air pollution and green space with depressive symptoms in adults: A LongITools cross-cohort analysis. *Environmental Research*, Volume 264, Part 1, 2025.
11 Sinkkonen A. et al. A Placebo-controlled double-blinded test of the biodiversity hypothesis of immune-mediated diseases: Environmental microbial diversity elicits changes in cytokines and increase in T regulatory cells in young children. *Ecotoxicology and Environmental Safety*, Volume 242, 2022.
12 Publication under review at time of going to print
13 https://www.humanexposome.eu/toolbox/
14 Tyrväinen et al. Health effect of natural environment and their economic impact. *Natural Resources Institute Finland*, 89 pp, 2024. (abstract in English on page 5–6).

Chemicals

Health risk data exists for only a fraction of the 100 000 chemicals on the market, including Endocrine Disrupting Chemicals (EDCs), pesticides and plastics. Several thousand of these chemicals cause widespread exposure in the population, and are potentially linked to immune diseases and allergies, neurological disorders, and endocrine disruption that affects fertility and metabolic health.

Examples of EHEN's exposome approach

EHEN has investigated complex chemical mixtures, their interactions with other exposures, and "early warning" biomarkers of a range of diseases. New techniques such **as non-targeted high-resolution mass spectrometry (HRMS)** have enabled EHEN researchers to simultaneously analyse thousands of chemical mixtures, and **"omics" technologies** (epigenetics, proteomics, metabolomics etc.) have enabled detection of molecular-level effects of chemical exposures in biological samples. These findings have been integrated with **harmonised clinical cohort data** to explore links between exposures and health outcomes over time.

Consumer Purchase Data (CPD) from loyalty programmes and digital receipts, when integrated with product databases and compared with clinical data, is also emerging as a promising source to assess the health effects of chemicals in everyday products.

~ 100 000 chemicals on the market

RISKS

HAZARDS   EXPOSURES

~ 500 chemicals
extensively characterised for
their hazards and exposures

~ 10 000 chemicals
fairly well characterised for a subset
of their hazards and exposures

~ 22 600 chemicals with a use over 1 tonne per year

~ 20 000 chemicals
with limited characterisation for
their hazards and exposures

~ 4 700 chemicals with a use over 100 tonnes per year prioritised in hazard characterisation and evaluation

~ 70 000 chemicals
with poor characterisation for
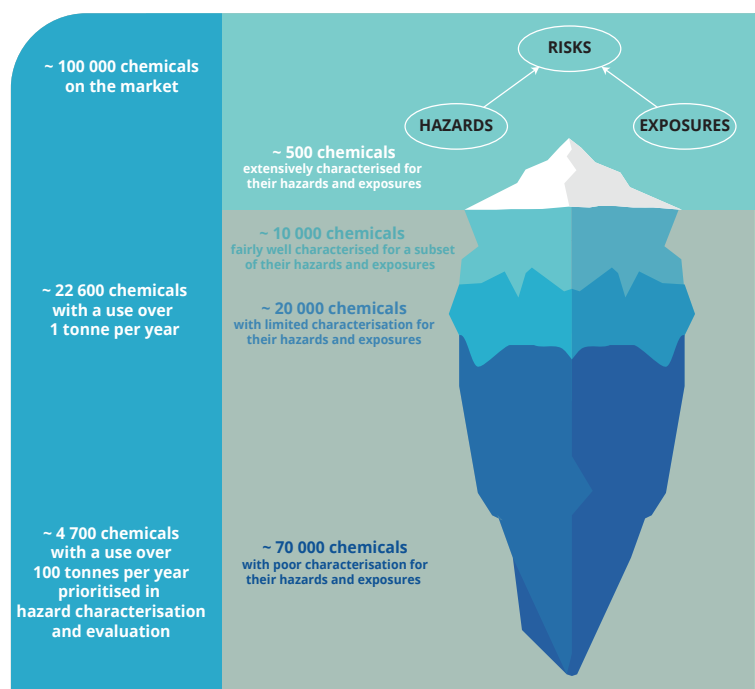their hazards and exposures

Fig. 3. The unknown territory of chemical risks (Source: EEA, The European environment — state and outlook 2020)

EHEN scientific evidence

Exposure to mixtures of EDCs are associated with higher **obesity risk in children**[15], with **children of lower socioeconomic backgrounds**[16] particularly affected.

Childhood chemical exposures[17] may cause pronounced molecular-level effects that are clinically undetectable until adulthood.

Prenatal exposure[18] perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) chemicals can increase the risk of childhood asthma.

Educating people on how to avoid chemicals[19] can reduce exposure to EDCs.

15 Güil-Oumrait N. et al. Prenatal Exposure to Chemical Mixtures and Metabolic Syndrome Risk in Children. *JAMA Network Open*, 2024.
16 Montazeri P. et al. Prenatal Exposure to Multiple Endocrine-Disrupting Chemicals and Childhood BMI Trajectories in the INMA Cohort Study. *Environmental Health Perspectives,* Volume 131, 2023.
17 Maitre L. et al. Multi-omics signatures of the human early life exposome. *Nature Communications* 13, 7024 (2022).
18 Chawes B. et al. Exposures to perfluoroalkyl substances and asthma phenotypes in childhood: an investigation of the COPSAC2010 cohort. *eBioMedicine*, Volume 94, 2023, 104699.
19 Yang T. et al. Interventions to Reduce Exposure to Synthetic Phenols and Phthalates from Dietary Intake and Personal Care Products: a Scoping Review. *Current Environmental Health Reports,* 10, 2023.

We are in a race against time when investigating harmful effects of new chemicals in products approved for sale. The European regulatory framework for chemicals, REACH, is lacking, despite progress on regulating classes of chemicals rather than individual chemical substances.

Martine VRIJHEID
Principal Investigator
ATHLETE project

Policy call to action

⬊ Use REACH to target the use of chemicals in production, processing, manufacturing, and packaging. Measures include leveraging the REACH Mixture Assessment Factor, and expanding the REACH Generic Approach to Risk Management (GRA) to the most hazardous substances.

⬊ Inform consumers on hazardous chemicals in products and packaging by promoting adoption of the EU Classification, Labelling and Packaging (CLP) regulation's new hazard classes, such as endocrine disruption, into the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

Health and Safety at Work

Occupational exposures such as welding and diesel fumes, mineral dust, organic solvents, heat, noise, heavy lifting and shift work, caused the loss of 90 million disability-adjusted life years (DALYs) in 2016 (World Health Organization). EHEN researchers collaborated with occupational health scientists to develop tools for evidence-based and cost-effective prevention of work-related diseases.

Examples of EHEN's exposome approach

- **Developed EuroJEM**[20], a tool for conducting occupational exposure assessments in large populations. It is built upon both harmonised and newly developed job exposure matrices (JEMs) from multiple countries, and addresses the most prevalent and significant occupational exposures.

- **Piloted minimally invasive biosampling**[21], a low-cost and efficient method enabling workers to take their own blood samples for molecular biomonitoring.

- **Trialled wearable sensors in the workplace**, and worked with occupational health and safety specialists to develop **guidelines for their successful and correct use**[22].

Fig. 4. Source: EPHOR project

EHEN scientific evidence

EHEN researchers collated and reviewed evidence on 200 occupational exposures to show which chemical, biological, physical and psychosocial exposures are linked to **over 60 non-communicable diseases**[23] to identify priority areas for future research. Moreover, some diseases, such as sarcoidosis, are associated to more than one exposure, each of which may promote a different disease phenotype.

During the COVID-19 pandemic, EHEN developed a job exposure matrix to gain insight into occupations with high exposure to COVID-19 and **the role of working conditions on infection risk**[24].

Both genetic background and exposure to silicates – (crystalline) silica and asbestos – are highly relevant to the development of (sub-) clinical systemic autoimmune disease.

20 https://ki.se/en/imm/eurojem
21 Ghosh M. et al. Characterization of the internal working-life exposome using minimally and non-invasive sampling methods – a narrative review. *Environmental Research*, Volume 238, 2023.
22 https://www.we-expose.eu/external-occupational-exposome-mapping
23 Peters S. et al. Narrative review of occupational exposures and noncommunicable diseases. *Annals of Work Exposures and Health*, 2024.
24 Oude Hengel KM. et al. The impact of occupational exposures on infection rates during the COVID-19 pandemic: a test-negative design study with register data of 207 034 Dutch workers. *Scand J Work Environ Health*. 2023.

Next steps for research and policy

- Build a framework for occupational **exposome passports** enabling the structured collection of personal exposure data to provide personalised risk assessments of developing diseases.

- **Use molecular biomonitoring** techniques to explore how occupational exposures such as mineral dust and organic solvents affect immune system responses.

- Investigate the dynamics of **non-occupational exposures** with working life, such as the effect of night shift work on diet, mental health and social and family relations.

> *EHEN has developed data, impact assessment approaches and early detection technologies to enable policy makers to shift their focus to preventive actions designed to stop workers falling ill.*

Anjoeka PRONK
Principal Investigator
EPHOR project

Policy call to action

Identify high-risk jobs or occupational exposures for future policy interventions with the European occupational exposure viewer (based on EuroJEM).

Research Data Management

EHEN has introduced simple and practical safeguards for using personal health data for research. These safeguards cover consent to participate in research projects, and also ensure anonymisation of personal data. These practical measures protect individuals' personal data and enable mass participation in scientific research, in compliance with the General Data Protection Regulation (GDPR).

Broad consent under GDPR

Challenge

Asking volunteers for consent to participate in data cohort studies. When recruiting volunteers, researchers always need to ask for consent to acquire their data and explain how the data will be used. If the terms of consent are too narrow, this can (often unintentionally) restrict use of the data for follow up studies.

Solution

Broad consent to share personal health data, while emphasising researchers' obligations to protect participants' interests, is the best way of managing consent in exposome research projects. What is more, broad consent for primary use of health data for research aligns with the European Health Data Space (EHDS) approach to secondary use of health data. Under the EHDS, citizens automatically consent to use their health data for research purposes, unless they specifically choose to opt out.

EHEN success story

Broad consent via web app

Study volunteers in the **MyPurchases cohort study**[25] use a GDPR-compliant, secure mobile app designed by EHEN researchers and approved by the Danish Data Protection Authority to donate their consumer data for health research. The app links to the participants' national digital signature to ensure they are correctly identified, and also access their personal health data. This case study proves that supervisory bodies can balance individual data privacy with the interests of scientific research.

Fig. 5. A citizen focus group to discuss the importance of exposome research (Source: EXPANSE)

Policy call to action

Policymakers should back broad consent for data processing. This departure from previous, more restrictive, interpretations of GDPR consent is ethically justifiable on the grounds of its future public health benefits. Broad consent is an essential enabler of exposome research.

25   T. Møller F. et al. Assessing household lifestyle exposures from consumer purchases, the My Purchases cohort. *Nature Scientific Reports* 13, 2023.
26   Groos D., van Veen E. Anonymised Data and the Rule of Law. *European Data Protection Law Review*, Volume 6, 2020.

> *Our message on using personal health data for scientific research is clear. We need a new balance between the rights of the individual on the one hand, and the collective "right to health" on the other.*
>
> *Getting this balance right will make sure that scientists can access the data they need to conduct high-quality research, and ultimately deliver the better public health outcomes we all want to see in our societies.*

Evert–Ben VAN VEEN
Chair, EHEN Ethics and Law Working Group

Anonymisation of personal data

Challenge

How can personal data be anonymised for research purposes? Researchers need reliable methods of ensuring data anonymity which balances the real risks of re-identification against the usability of these data for research.

Solution

The "Six safes"[26] model builds on case law from the Court of Justice of the European Union (CJEU), and proposes practical steps for researchers to follow to reduce the risk of re-identifying a data subject, while maximising the usability of the data.

> *EHEN has shown there are ways to prevent re-identification without compromising scientific progress or counteracting the will of study participants to have their data used for improving people's health and wellbeing.*

Heikki HYÖTY
Principal Investigator
HEDIMED project

Policy call to action

↘ For research institutions to be sure they are conducting scientific research within the law, legal clarity is essential. This is why EHEN is highlighting the "grey area" arising from differing interpretations of the scope of personal data under the GDPR, as European supervisory bodies and the CJEU hold divergent views.

↘ European case law (Patrick Breyer v Bundesrepublik Deutschland, SRB v EDPS) supports a risk-based approach to anonymisation of personal data. This view has not been taken into account by the European Data Protection Board (EDPB).

↘ To ensure that data anonymisation for scientific research remains feasible, EHEN is calling for the case law position to be clearly reflected in EDPB's guidelines on pseudonymisation and anonymisation.

6

Research Data Management (continued)

Exposomics relies on combining and analysing large data sets from many different sources. EHEN projects have pioneered ways of collecting and harmonising data for this emerging field of research.

EHEN success stories

Commercial data-gathering device

EHEN's model for research institutions to work with manufacturers and developers of wearable devices and apps (e.g., activity trackers) to gather data for observational studies includes the following conditions:

- The research protocol explains why it is necessary to gather data through the devices;
- Researchers receive only the data necessary for the study;
- The manufacturer guarantees GDPR-compliant data handling;
- Participants provide informed consent and receive an explanation of the manufacturer's privacy policy.

Findable, Accessible, Interoperable and Reusable (FAIR) data

The **European Health Research Data and Sample Catalogue**[27] is a result of multiple collaborations from many research and innovation projects, including EHEN. This online searchable tool, featuring metadata about EHEN's cohort studies, data sources, biobanks and registries, also contains harmonised data variables, making it easier to combine and analyse data from different sources and reduce the risk of errors and inconsistencies. The catalogue **facilitates data discovery**[28] and cross-study comparisons and expands the range of people and environments considered in research studies.

Future research will investigate the link between exposures and a wide range of non-communicable diseases, such as the link between pollutants and cancer, and between infections and immune diseases.

Fig. 6. Gathering exposome data (Source: LongITools)

The exposome concept

Fig. 7. The exposome describes the physical, chemical, biological and social influences on our health (Source: LongITools)

27 https://data-catalogue.molgeniscloud.org/catalogue/catalogue
28 Swertz M. et al. Towards an Interoperable Ecosystem of Research Cohort and Real-world Data Catalogues Enabling Multi-center Studies. *Yearb Med Inform* 2022.

References

Urban health

1 Revealed: almost everyone in Europe is breathing toxic air. *The Guardian*, 20 September 2023.

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8 Seastedt H. et al. Impact of urban biodiversity and climate change on children's health and well-being. *Pediatric Research*, 2024.

9 Fernandes A. et al. Green spaces and respiratory, cardiometabolic, and neurodevelopmental outcomes: An individual-participant data meta-analysis of > 35 000 European children. *Environment International*, Volume 190, 2024, 108853.

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11 Sinkkonen A. et al. A Placebo-controlled double-blinded test of the biodiversity hypothesis of immune-mediated diseases: Environmental microbial diversity elicits changes in cytokines and increase in T regulatory cells in young children. *Ecotoxicology and Environmental Safety*, Volume 242, 2022, 113900.

12 Publication under review at time of going to print

13 https://www.humanexposome.eu/toolbox/

14 Tyrväinen et al. Health effect of natural environment and their economic impact. Luontoympäristön terveysvaikutukset ja niiden taloudellinen merkitys. Luonnonvara- ja biotalouden tutkimus 76/2024. *Natural Resources Institute Finland*, 89 pp, 2024. (abstract in English on pages 5–6).

Chemicals

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Health and Safety at Work

20 https://ki.se/en/imm/eurojem

21 Ghosh M. et al. Characterization of the internal working-life exposome using minimally and non-invasive sampling methods – a narrative review. *Environmental Research*, Volume 238, 2023, 117001.

22 https://www.we-expose.eu/external-occupational-exposome-mapping

23 Peters S. et al. Narrative review of occupational exposures and noncommunicable diseases. *Annals of Work Exposures and Health*, 2024, 10.1093.

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Research Data Management

25 T. Møller F. et al. Assessing household lifestyle exposures from consumer purchases, the My Purchases cohort. *Nature Scientific Reports* 13, 2023, 21601.

26 Groos D., van Veen E. Anonymised Data and the Rule of Law. *European Data Protection Law Review*, Volume 6, 2020, Issue 4.

27 https://data-catalogue.molgeniscloud.org/catalogue/catalogue

28 Swertz M. et al. Towards an Interoperable Ecosystem of Research Cohort and Real-world Data Catalogues Enabling Multi-center Studies. *Yearb Med Inform* 2022:262–72.

This policy brief was written collectively by the nine EHEN projects and includes only a sample of the evidence and knowledge gathered.

EHEN project overviews

The EHEN research projects received over 100 million euros from Horizon 2020, the EU framework programme for research and innovation, to study the impact of environmental exposures on human health.

ATHLETE
The Exposome from Evidence to Translation

ATHLETE measures multiple environmental exposures (urban, chemical, lifestyle, and social risk factors) during pregnancy, childhood, and adolescence and links them to children's biological responses and cardiometabolic, respiratory, and mental health.
athleteproject.eu

EPHOR

EPHOR studies the working-life exposome and aims to reduce the burden of Non-Communicable Diseases (NCDs) on EU healthcare systems, improve the productivity of the EU workforce, and increase the competitiveness of EU industry.
ephor-project.eu

Equal-Life

Equal-Life develops and tests combined exposure data using a novel approach to multi-modal exposures and their impact on children's mental health and development.
equal-life.eu

EXIMIOUS

EXIMIOUS maps exposome, immune system (immunome), other omics, and clinical and socio-economic data to identify "immune fingerprints' that are early signs of poor health and predictors of disease.
eximious-h2020.eu

EXPANSE

EXPANSE aims to decrease unexplained Cardio-Metabolic and Pulmonary Disease (CMPD) risk in urban populations and to gain insights into mediating biological mechanisms and causality.
expanseproject.eu

HEDIMED

HEDIMED identifies exposomic determinants behind the rapid increase of immune-mediated diseases (IMDs) such as type 1 diabetes, celiac disease, allergies and asthma.
hedimed.eu

human exposome assessment platform

HEAP provides an integrated informatics and software platform for handling and analysing large amounts of data on environmental exposures and their health effects.
heap-exposome.eu

longITools

LongITools studies interactions between the environment, lifestyle and health in determining the risk of developing chronic cardiovascular and metabolic diseases.
longitools.org

REMEDIA
IMPACT OF EXPOSOME ON THE COURSE OF LUNG DISEASES

REMEDIA studies the contribution of the exposome to chronic obstructive pulmonary disease (COPD) and cystic fibrosis (CF).
h2020-remedia.eu

For further information about the European Human Exposome Network, scan the QR code to visit **www.humanexposome.eu** or contact Heather COOMBS by email at **coombsh@iarc.who.int.**

www.humanexposome.eu