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Setting up a network of experts for developing a guidance document on how to deal with human biomonitoring in PFAS hotspots

Activity Report

WP 5 Science to Policy - PFAS CGL

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1 Authors

This document resulted from a collaboration between the HBM4EU PFAS hotspot coordinating team (lead authors of this report), HBM4EU contributors and additional members of the PFAS hotspot network (beyond HBM4EU). This network was launched early 2022, and involved scientific experts, environmental health care workers and regulatory authorities involved in PFAS hotspots throughout Europe.

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2 Introduction

2.1 Preface: why a PFAS hotspot network?

Exposure to per- and polyfluoroalkyl substances (PFAS), a widely-used class of persistent chemicals, has been linked to an array of adverse health outcomes. While most individuals in Europe are exposed to background-levels of PFAS, some populations living near contaminated sites ('PFAS hotspots') are exposed at moderate, high or extremely high levels. Several PFAS hotspots have been identified in various regions in the EU, and new PFAS hotspots continue to be discovered. There is a large public health concern within several of these PFAS hotspots. In order to address the health concern of citizens living in the neighbourhood of PFAS hotspots, human biomonitoring in hotspot regions have been conducted, or are ongoing or planned.

Within the HBM4EU project, the need for a network of experts addressing PFAS exposure in hotspots in EU has been recognised. The Management Board of HBM4EU approved during the MB meeting of 18 November 2021 to launch an activity on PFAS in hotspots.

2.2 Organization and activities of the PFAS hotspots netwerk

The PFAS hotspot network was set up early 2022. Invitations to join the PFAS hotspot network were distributed among the HBM4EU partners. Additionally, we invited also authors of publications regarding PFAS human biomonitoring in hotspots in Europe (e.g. Italy: Veneto; Sweden: Ronneby; Germany: Arnsberg, Rastatt and Altötting). The following countries were represented in the network: Austria, Belgium, Germany, Denmark, Italy, Sweden, the Netherlands, Iceland, UK, Norway and Hungary. The list of network members is mentioned in section 1 of this report.

Between January and April 2022, 3 online network meetings took place. During these meetings, various experiences and views on human biomonitoring (HBM) in PFAS hotspots have been shared within the network. Agenda's, meeting minutes and presentations of these meeting can be obtained upon request.

The collaboration within the network resulted in four main outcomes, which are reported in the following sections of this report :

- An **inventory** of human biomonitoring studies in PFAS hotspots in Europe was created: overview the exposure levels, type and source of the contamination, exposure determinants, health research and policy impact of PFAS contamination at various hotspots across Europe (see chapter 3 of this report)

- A **workshop on PFAS hotspots** was organized (2 May 2022). During this half-day workshop, the knowledge and challenges related to PFAS hotspots across Europe were presented and discussed with European, regional and local risk managers of contaminated sites, environmental health care workers, scientists, and regulatory authorities involved in chemical risk assessment (minutes of this workshop: see chapter 4 of this report)

- A **guidance document on identification and monitoring, human biomonitoring, and risk communication in PFAS hotspots** has been drafted via collaboration within the network. The guidance aims to be useful for policy makers and scientists confronted with new PFAS hotpots (guidance document: see chapter 5 of this report).

- **Recommendations** for further research and policy recommendations (chapter 6 of this report)

3 Inventory of information on human biomonitoring in PFAS hotspots in Europe

In a first stage of this project, an inventory of HBM studies at PFAS hotspots was made. The inventory is based on searches in scientific literature, and input from network members who were aware of existing studies in their country. The latter type is additional to the scientific literature, since several reports are published in the 'grey' literature, often published in native language of the affected hotspot (non English report).

The inventory was made according a structured approach, including fields such as pre-phase, public concern, biomarkers of exposure, biomarkers of effects, information on determinants of exposure, risk communication and impact at societal and policy level. This structure was based on a format developed within the ICSNet project, related to human biomonitoring studies at industrially contaminated sites (Colles et al.2019).

The inventory included cases around several types of PFAS pollution sources. The first type includes studies around PFAS production sites. For example, PFAS was monitored in serum of residents in Zwijndrecht (Belgium) (VITO, 2021); in residents of the Veneto Region Italy (Ingelido et al., 2018) and in people living in Dordrecht in the Netherlands (RIVM, 2017) in the neighbourhood of a PFAS production site. Other studies have investigated PFAS serum levels of residents living in the neighborhood of sites contaminated due to the use of firefighting foam: two studies in Sweden, i.e. Ronneby and Arvidsjaur (Xu et al., 2021, (Xu et al., 2020)); one study in Denmark, namely in Korsør) (Lyngberg, 2022), and sites contaminated by the extensive application of soil conditioner/fertilizer on agricultural area (e.g. Arnsberg study in Germany; Hölzer et al., 2008). In Norway, a PFAS hotspot related to a paper industry site has been reported (Langberg et al., 2021).

The inventory of this information, including study results and impact, is available as technical background document (pdf format: see Annex 1). The excel version of this inventory can be obtained upon request.

The overall trends on exposure levels, exposure determinants and policy impact of PFAS contamination at various hotspots across Europe are summarized here:

3.1 Exposure levels and exposure determinant

Information from human biomonitoring studies in populations living near contaminated sites demonstrate that these populations are exposed at moderate, high or extremely high levels in serum. For example, in Ronneby the geometric mean (GM) of the exposed population was 239 ng PFOS/ml; in Zwijndrecht: the GM was 22.4 ng/ml PFOS; in the Veneto region: GM: 35.8 ng PFOA/ml and in Korsør: 43 ng PFOS /ml (Lyngberg, 2022). These values largely exceed background levels of the general population in Europe.

Dominant PFAS compounds, exposure routes and sources, severity of the contamination, and options for remediation are diverse across different PFAS hotspots. While in Ronneby and Zwijndrecht, PFOS was the dominant compound in the environment and the serum samples, in the Veneto Region and Dordrecht was a clear dominance of PFOA in the serum profiles. Main sources of PFAS contamination at hotspots are (historical) PFAS production sites, or sites where use of PFAS containing products contaminated the soil and groundwater, for example use of PFAS-containing firefighting foams or PFAS-contaminated sludge used as soil improving materials. Also, dominance of exposure routes is diverse. In Ronneby, and Veneto, the contamination of the municipal drinking water was the dominant source for human exposure. At other hotspots, contamination throughout the local food chain was the main current exposure route, related to consumption of locally produced meat (Korsør), chicken eggs (Zwijndrecht) or fish. Notwithstanding the role of the inhalation pathways currently is probably minor, the contribution of inhalation of PFAS contaminated air in the past (historical emissions to air around PFAS production sites) may still be reflected in current PFAS serum levels. Modelling using historical PFOA emissions indicated past inhalation exposure as the dominant exposure route among residents in Dordrecht (around a PFOA production site, Oomen and Herremans (2017)).

The diversity in PFAS profiles and routes of exposure at these investigated PFAS contaminated sites demonstrates the need for site specific investigation of exposure routes, including accounting for the land use of the contaminated sites, consumption of local food products, and drinking water source(s).

Although the focus of the inventory was on human biomonitoring studies, we found also some studies on PFAS hotspots where monitoring data of local produced food and drinking water was the starting point used to assess the exposure and to perform a risk assessment for the population concerned. In addition to such a ‘prospective’ exposure assessment based on monitoring data of environmental media, often human biomonitoring is set up and complements information which can often not be assessed using modelling by lack of data (e.g. the role of historical exposure, routes and sources that may be neglected in modelling).

3.2 Policy impact related to PFAS hotspots

Human biomonitoring results from PFAS hotspots in different regions across Europe have caused societal concern, received significant media attention, and escalated often to political “PFAS crises”. Communities have wondered why PFAS contamination was not prevented or detected and remediated earlier, and have blamed politicians, policy makers and the polluters for gross negligence in protecting people against PFAS exposure.

During and after first crisis management at PFAS hotspots, several policy actions were installed. In Italy, a research commission was set by the Italian Parliament to amend the relevant laws about PFAS. In Belgium a Research Commission was set by the Parliament investigating for responsibilities, and a PFAS Coordinator was assigned by the Flemish Government, having the mandate to enhance collaboration at various local and regional environmental and health administrations and to elaborate the way forward to a sound integrated policy for persistent chemicals. In Austria, improved cooperation between different authorities was set up and shall be further developed, to enable cross-sectoral coordination depending on the escalation level (routine activities, emergency management and crisis management). In Sweden, a PFAS Platform coordinated by the Chemicals Agency (together with the EPA and Food Agency) meet on a regular basis to exchange on PFAS. Also, researchers and consulting institutions are involved in a broader network which meets every half year in Sweden. In Denmark, after the Korsør case was public, the regions identified potential additional hotspots, the health authorities issued information material to the public and the general practitioners. The Danish EPA has the role as coordinating institution also giving advice to local communities. In other countries the exchange is more random. Often actions are set in states/regions and not coordinated at federal level.

In several regions and countries, the PFAS crisis give rise to the amendment of relevant laws about PFAS, e.g., stricter limit values for PFAS in drinking water and stricter emission limits of PFAS to the environment. Screening and identification of additional hotspots (see above) and enhanced monitoring of PFAS in the environment was set up in several hotspots (and beyond hotspots). For example, in Denmark requirements were set for water suppliers to screen for PFAS; in Austria monitoring food that is produced in the contaminated region is continuing as well as monitoring of ground water and searching for the cause of contamination. Risk management and remediation is obviously tailored towards the dominant routes of exposure: e.g., in Ronneby disconnection of the contaminated well water from the municipal water supply reduced drastically the exposure and resulted in declines of PFAS serum levels a few years after this remediation. In Zwijndrecht (Belgium), residents are advised to stop the consumption of locally produced eggs, comparable to the advice against consumption of local caught fish in other hotspots. Remediation of the source is more demanding in settings where direct or indirect exposure to PFAS in soil is a relevant exposure route. The industry responsible for the pollution in Zwijndrecht promised to allocate budget for remediation of gardens in the neighbourhood.

These examples demonstrate that environmental contamination (in case of PFAS) has led in several regions in Europe to policy crisis and distrust of citizens in authorities and industry due to failure of governance and environmental management. Furthermore, it has been shown that targeted and clear communication is particularly important in crisis management of (PFAS) hotspots. In several affected regions, (post) crisis policies are set up to remediate sites, to prevent further pollution and to screen other potential PFAS hotspots.

3.3 From experiences to guidance for upcoming PFAS hotspots

It is more than likely that new PFAS hotpots will pop-up in the future in several countries and regions. Based on the experience, good practices and interactions with experts from different hotspots, the PFAS hotspot network group draft a guidance that can be used by authorities and researchers facing new PFAS hotspots.

The guidance is presented in chapter 5 of this document, and consist of three parts:

- Guidance on identification and monitoring
- Guidance on human biomonitoring (HBM) at PFAS hotspots
- Guidance on risk communication

The guidance was developed by members of the network, and the draft guidance document was discussed during the HBM4EU PFAS hotspots workshop (workshop: see chapter 4). The insights and suggestions we received from the workshop participants have been incorporated in final version of the guidance document on identification and monitoring, human biomonitoring, and risk communication at PFAS hotspots (final version of this guidance: see chapter 5 of this report).

4 Workshop on PFAS hotspots

A half-day workshop was organized to present the knowledge and challenges related to PFAS hotspots across Europe, and to interact with stakeholders and potential users of the guidance document. The workshop was held online (using MS Teams) on 2 May 2022.

In the first part of the workshop, an overview of practices, views and lessons learnt and policy impacts of human biomonitoring studies in PFAS hotspots across Europe have been presented. In the second part of the workshop, the draft guidance document was discussed in parallel break-out sessions: 1) identification and monitoring of PFAS hotspots, 2) biomonitoring and health, and 3) risk communication in PFAS hotspots.

4.1 Programme of the workshop

HBM4EU PFAS hotspot Workshop 2 May 2022 (10.00 – 13.00) **Human biomonitoring as a tool to address public health concerns in PFAS hotspots: investigation, communication and risk management**		
10:00 – 10:05	Checking connections	
10:05 – 10:20	Welcome and Introduction to the workshop's programme and its goals Short introduction to HBM4EU – science to policy (pilar I)	Maria Uhl (EAA) chemical groups leader PFAS Greet Schoeters (VITO), pillar I lead
Session 1 (plenary)		
10:20 – 10:45	Human biomonitoring in PFAS hotspots in Europe: overview and experiences	Katleen De Brouwere (VITO)
10:45 – 11.05	Policy impacts of PFAS contamination at hotspots in Europe	Maria Uhl (EEA)
Session 2 (discussion in 3 parallel break out rooms)		
11:10 – 12.20	WG 1: identification and monitoring PFAS hotspots	WG moderator: Lisbeth E. Knudsen (UCPH)
11:10 – 12.20	WG 2:biomonitoring in PFAS hotspots	WG moderator: Ann Colles (VITO)
11:10 – 12.20	WG 3: risk communication in PFAS hotspots	WG moderator: Elly Den Hond (PIH)
12:20 – 12.30	*Break*	
Session 3 (plenary)		
12:30 – 13.00	Reporting outcome of working groups	WG 1 reporting: Maria Uhl (EAA)

		WG 2 reporting: Liese Gilles (VITO) WG 3 reporting: Ilona Gabaret (PIH)
	Wrap up, conclusions and next steps	Katleen De Brouwere (VITO)

4.2 Workshop Participants

The workshop has been attended by about 100 participants, from 58 different institutes, universities, agencies or other organizations. The audience consisted mainly of European, regional and local risk managers of contaminated sites, environmental health care workers, scientists, and regulatory authorities involved in chemical risk assessment. In terms of European level organizations, there were representatives from the European Commission (EC DG RTD and EC DG SANTE), ECHA, EFSA and WHO Regional Office for Europe. In view of coverage within Europe, participants from the following countries attended the workshop: Austria, Belgium, Germany, Spain, Denmark, Italy, Sweden, the Netherlands, Iceland, Portugal, UK, Greece, Norway, Slovakia, Hungary and Ireland. We also had some participants from outside Europe (i.e. Health Canada).

We had a stable number of participants during the workshop, and an balanced distribution of participants in the 3 break out sessions.

4.3 Reflections on workshop break out sessions

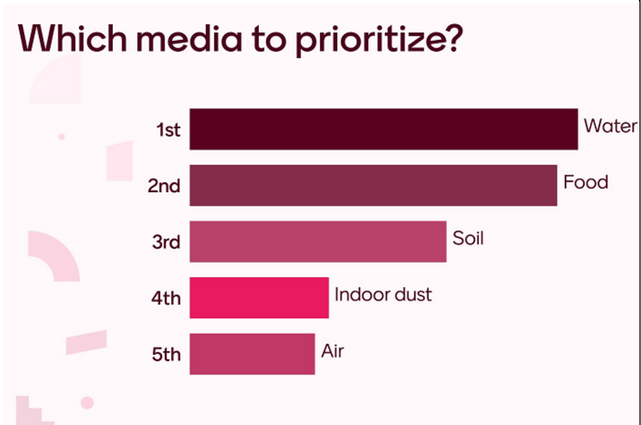
In three parallel break-out session, participants exchanges ideas and gave feedback on the draft guidance document which was distributed to the participants prior to the workshop.

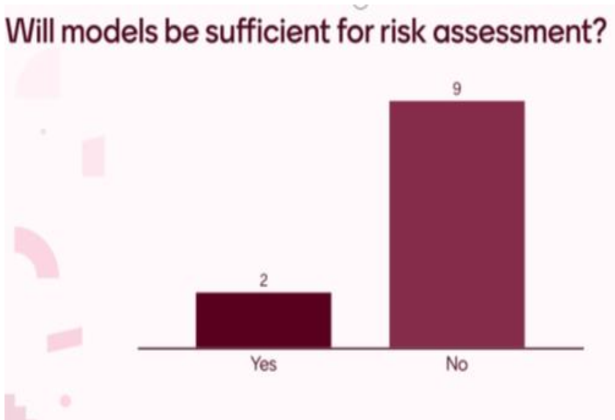
The insights and suggestions we received from the participants have been incorporated in final version of the guidance document on identification and monitoring, human biomonitoring, and risk communication at PFAS hotspots (see Annex 1 of this workshop report)

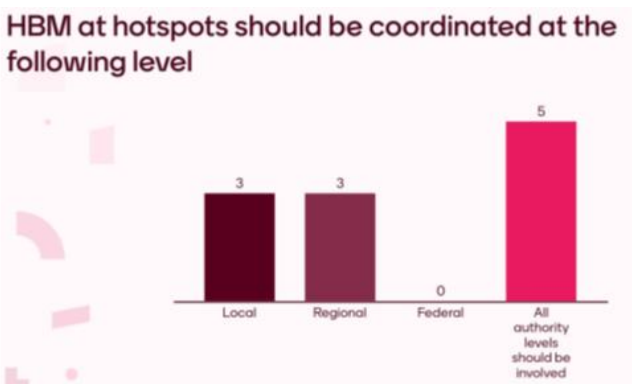
At end of parallel break-out sessions, a poll was organized to gather opinions of workshop participants on several topics regarding monitoring, prioritization, human biomonitoring and risk communication. The poll was organized at the end of the sessions.

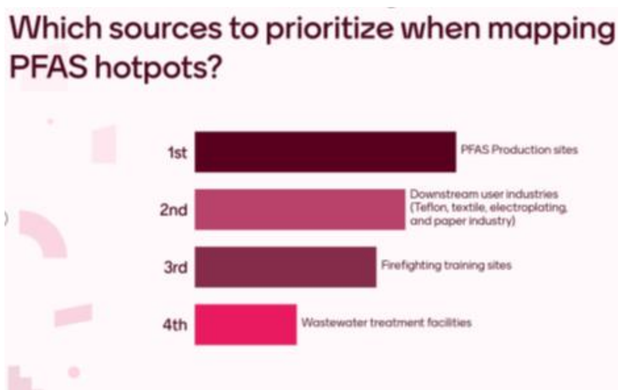
The results of the polls are depicted here, and reflect the aggregated opinions of the participants of each session.

4.3.1 Results of the poll in session "identification and monitoring PFAS hotspots"

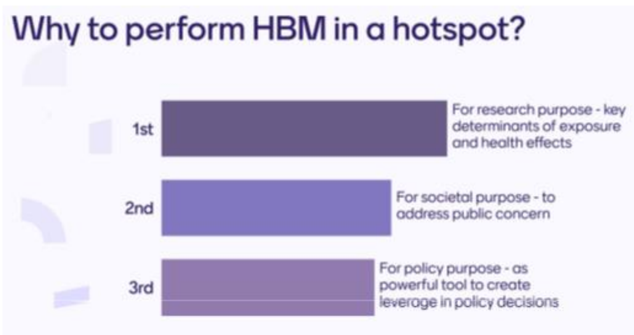


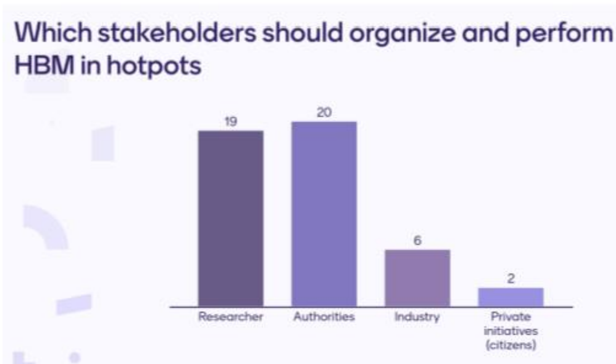


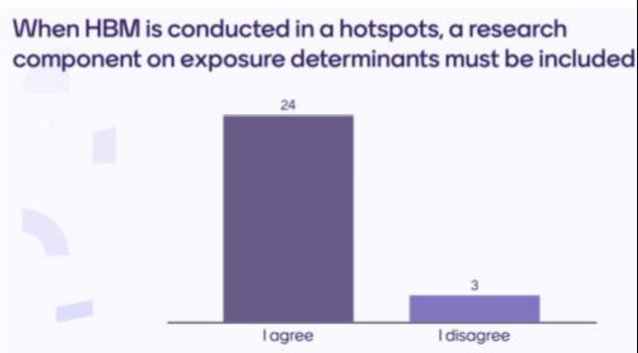


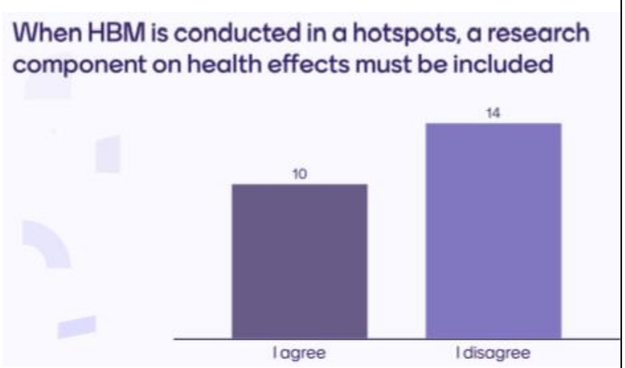


4.3.2 Session "biomonitoring in PFAS hotspots"

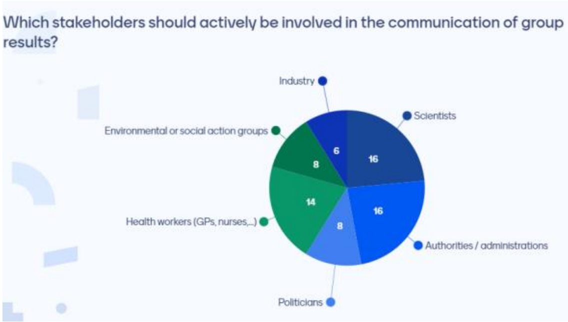


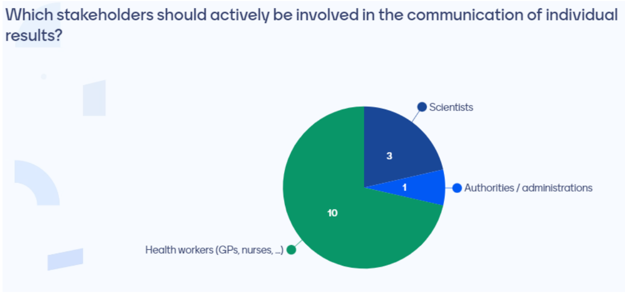




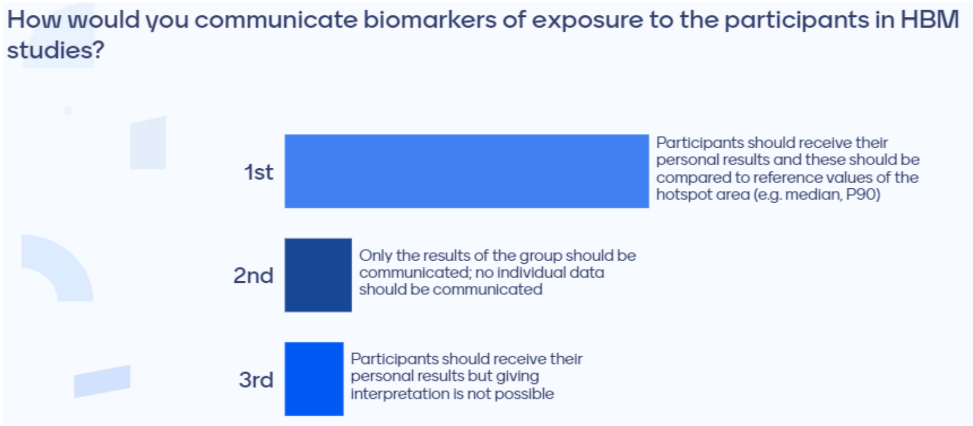


4.3.3 Session "risk communication in PFAS hotspots"





Note: options 'policitans' and 'industry' received no votes for this question



5 Guidance document on identification and monitoring, human biomonitoring and risk communication in PFAS hotspots

5.1 Guidance on identification and monitoring of PFAS hotspots

In order to take further measures such as exposure monitoring, human biomonitoring, and remediation, it is necessary to identify the affected areas. This can be done in different ways, more randomly or through targeted research and investigations, as there is already knowledge about the causes of PFAS contamination. In some countries, especially those that have faced severe contamination cases, more strategic research has been conducted or started. However, in many countries, this has not yet been addressed.

Identification of PFAS contaminated sites and potential hotspots is important to limit exposure to humans. Especially the authorities (local, regional and national) involved must be clarified and involved in the remediation and communication. Based on the European knowledge- and experience sharing, recommendations for early identification can be formulated. This shall guide the early identification of contaminated sites. It will include a description of the most common hotspots based on the European experiences and where and how to monitor PFAS in the environment.

When identifying PFAS hotspots, it is important to consider the source of contamination. Is the source a previously derived contamination, which is not any longer an active polluter, or is it a current polluter? If so, it is important, if possible, to stop and limit further contamination of the site.

Most common hotspots

Common hotspots seen in Europe are firefighting training and drill facilities including airports and military areas. The industries where PFAS have been used or produced are another common site of larger PFAS discoveries. These are often chemical plants, as well as production where PFAS is being used as a part of the product, such as the Teflon, textile, electroplating, and paper industry. Further downstream use applications have to be considered. Other important (potential) exposure sources are landfills and wastewater treatment facilities. To identify contamination pathways, it could also be useful to track pathways of industrial waste and sewage sludge.

Many of the contaminated sites have been discovered by coincidence while examining the environment for other substances. In Denmark, large amounts of PFOS were found when testing the wastewater for remains of medication. In Austria a drinking water survey has shown elevated levels at certain sites.

Exposure and Monitoring of hotspots

Systematic monitoring of drinking water and food as well as water within the frame of the water framework directive allows to identify elevated PFAS levels.

In case a hotspot is identified, environmental monitoring should be the first step. Modelling can be an approach to estimate human exposure, e.g., in case of primarily drinking water contamination. In case there are additional sources (e.g., meat, vegetables, eggs, fish) the model needs to be expanded. Also, physiological based pharmacokinetic (PBPK) models are useful for more in-depth assessments, for predicting the impact of environmental pollution on internal PFAS levels (e.g. in serum).

Other sources of exposure should be considered as well, although they might be of minor importance: inhalation and dermal uptake (e.g., from soil, and swimming pools, showering). In addition, exposure sources for the general population have to be taken into consideration (consumer products such as cosmetics, food contact materials, textiles and cleaning products).

General Recommendations

The identification of sources is essential; here, information must be gathered from several levels and by different responsible bodies (e.g., EU register, chemical and labour inspectors, chamber of commerce and industry).

Federal, State and Regional Authorities, Environment (Protection) Agencies might have knowledge and data for identification of potential hotspots. It is important that all authorities work closely together, by exchanging data, information and knowledge and that transparency and availability and exchange of data is guaranteed.

In particular, the recording of PFAS emissions by the EMREG register is a priority. Monitoring of emissions to water and air is a prerequisite for this. However, this is absolutely necessary so that limit values can be derived in a subsequent step.

There is also a need for method development for monitoring of PFAS (AOF, Total Organic Fluorine, Top Assay). In general, the availability of harmonised and validated methods for different matrices is a prerequisite for further investigations. The establishment of binding limit values is urgent. Furthermore, the EU-wide restriction of all PFAS except for essential uses should be supported.

A survey of all hotspots is necessary and must follow a structured approach ensuring documentation, transparency and availability. One priority area to be addressed is the registration of historical firefighting training and extinguishing agent storage sites of fire brigades, as well as their systematic investigation and assessment. As an example of such a systematic mapping of historical firefighting training and extinguishing agent storage sites of fire brigades PFAS hotspots, we can refer to the Flemish tool 'PFAS verkenner' (https://www.dov.vlaanderen.be/portaal/?module=pfasverkenner) being an online visualisation tool, mapping > 800 sites across Flanders and reporting gradually the status of monitoring at these sites, leading to confirmation or rejection of the site as being PFAS contaminated. As another example is the Danish website providing an overview of water sources contaminated https://www.danskevv.dk/viden-om/pfas/oversigt-over-fund-af-pfas/. In September 2021 a survey of 145 potentially polluted fire extinction sites was published in Denmark (https://www.beredskabsinfo.dk/brandvaesen/her-er-de-145-brandoevelsespladser-der-skal-undersoeges-for-giftigt-stof/). The mapping was extended towards other sectors. At the moment of drafting this report, almost 15000 sites have been identified in Denmark by the Regions as potentially contaminated (see https://www.tvsyd.dk/syd-og-soenderjylland/knap-15000-steder-boer-undersoeges-for-forurening-af-fluorstoffer) . In Austria the POPMON project, industrial and waste treatment sites, as well as suspected and contaminated sites, have been identified in the POPMON project (https://wissenaktuell.ages.at/download/0/0/c8d74003a4c6b74e4f2a773470f3a9c2f23200a8/fileadmin/AGES2015/Wissen-Aktuell/Wissen_aktuell_2021/Endbericht_POPMON_II.pdf. These site are identified as having a potential risk of environmental contamination with POPs and subsequently of contamination of food and drinking wate In Austria.

The Norwegian environmental protection agency identified 50 airport sites (use of firefighting foams), 300 municipal fire fighting training centres and a few other industrial sites (paper pulp industry) as PFAS affected sites in Norway.

The development of remediation concepts and guidelines for soils and soil replacement as well as subsequent management of the sites (harmonized remediation thresholds throughout Europe) is needed.

The EU have made a recommendation to monitor PFAS in food (2010/161/EU). The recommendation can be found at

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010H0161.

5.2 Guidance on human biomonitoring (HBM) at PFAS hotspots

Based on the experiences in the European PFAS hotspot cases **we reflect and provide guidance on the use of human biomonitoring as a tool in policy and research context and give some recommendations** for further research and policies where HBM PFAS can be considered.

This guidance document is tailored towards the use of human biomonitoring within a policy and research context to investigate exposure on population level. The use of human biomonitoring on the level of single individuals within a clinical context is out of scope of this guidance. This would require a separate guidance document. Sampling from humans outside the clinical context always requires informed consent which should also address the right of the participants to know or not to know their own results as well as consent of sample to be used in eventual future studies.

5.2.1 When is HBM (not) recommended in a PFAS hotspot?

The question on whether and how to use HBM in hotspots is not limited to PFAS hotspots only; it applies to a variety of contamination types. Within the COST Action IS1408 'Industrially Contaminated Sites and Health Network (ICSHNet)' a paper was published discussing the potential and limitations of HBM to assess exposure and early health effects associated with living near an industrial contaminated site (ICS) (Colles et al., 2019). The scope of PFAS hotspots is broader than ICS (e.g. also firefighting training sites), but the principles and advice gathered in this paper were useful as a basis, together with the practices and views in different PFAS hotspots and countries. Mind that within this document no 'strict' guidance is provided (given the diversity of opinions within the network, and that a one-fits-all solution is not applicable), but rather a list of reflections to consider when deciding to perform or not to perform HBM in a PFAS hotspot.

5.2.1.1 Why to perform HBM in a PFAS hotspot

5.2.1.1.1 For research purposes

HBM is a useful tool to answer specific research questions. PFAS levels in serum are a robust marker for individual exposure, and validated and harmonized protocols to measure PFAS in serum are available (e.g. HBM4EU accreditation of monitoring PFAS in serum). Other matrices such as whole blood, serum urine and breast milk can be alternatives (Jian et al., 2018; Poothong et al., 2017). Based on the inventoried PFAS hotspot cases, several categories of research questions can be distinguished:

- Investigating the extent of the PFAS exposure in the hotspot population: HBM provides an integrated picture of PFAS exposure or body burden from all the present sources and routes of exposure combined. HBM allows to overcome potential shortcomings of missing exposure routes/sources which might occur when exposure assessment is based on modelling or environmental monitoring only, or when insufficient data are available as essential input for modelling (especially regarding the duration of exposure; historical monitoring data are in general lacking, though are very relevant because PFAS bioaccumulate). Experts from different hotspots (e.g., Ronneby, Veneto, Zwijndrecht, Korsør) report they would have had no idea of the (strongly) elevated serum levels measured in the population without human biomonitoring (or at least: the levels would have been underestimated in most cases given the lack of historical environmental monitoring data and knowledge of the duration of the exposure).

- Investigating key determinants of exposure: Combining PFAS HBM data with available information on sources, environmental levels or questionnaire data on population characteristics can provide more detailed information on main routes of exposure, highly exposed subpopulations or specific characteristics associated with increased or decreased body burdens.
- Investigating health effects related to PFAS body burdens in hotspot populations: Availability of PFAS serum levels at an individual level facilitates in-depth research combining other individual data such as paired measurements of biomarkers of effects, data on health, and information on relevant confounders and covariates such as habits, socioeconomic and geographic data. Results of human biomonitoring investigating health effects can help to reduce uncertainties in risk assessment. Insignificant effects should be interpreted with caution and careful consideration of the study power.
- Investigating ways to accelerate PFAS elimination from the human body (especially vulnerable groups and susceptible windows of life, e.g. women in childbearing age)

5.2.1.1.2 For policy purpose

The results of HBM in a PFAS hotspot are often experienced as powerful to create leverage in policy decisions (remediations, restrictions, setting stringent rules for PFAS uses/production sites, e.g., emissions, etc.).

- Since HBM exposure data have a stronger relevance for health than environmental data (HBM: are also perceived as more ‘personal’ than ‘environmental monitoring data’), it is experienced as a stronger tool for policy making/need for action (also in public debate and media attention). Additionally, results on associations between exposure levels and health effects in the affected populations can be strong signals for remediating actions.
- Results concerning determinants contributing to increasing or decreasing exposure levels within the population can offer leverage points for targeted policy actions.

5.2.1.1.3 For societal purpose

- HBM is often initiated to address public concern about exposure and the related health risks for residence in a hotspot; the decision to perform HBM likely gives trust to the affected population that their concern will be adequately investigated, and their concern is not ignored.
- The right to be informed: Residents of PFAS hotspots experience unvoluntary exposure through a failure of governance and environmental management, and therefore should have the right to get informed to what extent the local population is exposed, even if the health implications are unclear. HBM can be a first step in assessing the PFAS exposure of a specific population. When HBM is performed as (part of) a hotspot research setting, guidance on the communication of the aggregated and the individual results is needed to avoid or minimize additional stress and concerns with participants (see also section 5.2.1.2). This is addressed in a separate subchapter of this guidance document (see section 5.3). HBM is one of the available tools to obtain this information, but not the exclusive one. Alternatively to HBM, environmental monitoring data and modelling tools can also provide this information (if models are sufficiently parameterized and validated; this should be considered case by case).

5.2.1.2 Pitfalls that need attention

- The size of hotspot and the affected population (or the subpopulation of concern) might be too small for a meaningful HBM study (guidance of ICSHNet is minimum of 100 participants in a hotspot study to get a population-representative exposure ranges). Smaller studies can be helpful for validation of modelling.
- Knowledge on PFAS levels in serum may not help to improve the health status of the affected population. The knowledge gained from HBM studies needs to be implemented in strategies focusing on exposure reduction and health improvement of the affected population. This requires certain responsibilities taken up by stakeholders and government. HBM makes pollution personal, but this comes with a downside:
    - Communication of PFAS body burdens can cause additional **stress**. A qualitative study in contaminated sites in Australia reported that participants were concerned about potential physical health effects of exposure to PFAS, such as cancer clusters, unexplained deaths, potential exacerbation of existing health conditions, and the future health of their children (Banwell et al., 2021). They expressed feelings of stress and anxiety about living with uncertainty related to the possible health and the socio-economic impacts of PFAS contamination in their communities. *Perhaps the stress and anxiety are worse than the direct PFAS related health risks.* Positive interactions with government responders and health care providers may help reduce negative stress. Also mass media reporting has a strong impact on the stress and anxiety. Good risk communication about the usually low health risks of PFAS exposure in relation to other risk factors for disease is important (see section 5.3).
    - PFAS serum levels have no clinical relevance on individual level since the related diseases are multifactorial and the role/contribution of the PFAS exposure cannot be quantified. Measuring of PFAS in serum should therefore not be performed out of scope of a policy/research project (where the focus is on group). Furthermore, PFAS levels cannot aid in predicting later development of diseases on an individual level and no treatment is available to reduce body burdens.
- The costs of performing a HBM study might be high and should/can be put in perspective whether these resources can be better allocated to remediation actions or other health benefits or compensations for the affected population.

5.2.1.3 Who should set up and coordinate HBM in PFAS hotspot?

A **coordinated organization** of HBM studies by authorities, and/or in collaboration with research groups is preferred.

- This gives in most cases confidence to the affected communities in a proper study design and quality of the study.
- It creates opportunities for larger study populations allowing group interpretation of the results, which cannot be obtained on separate individual results only.
- While the initiative to coordinate HBM in a hotspot is preferably coordinated by authorities and/or researchers, it is very important to foresee participation with local stakeholders throughout the process (see section 5.3).

Organization by **private initiatives/citizen groups**: Some citizens in hotspots might distrust authorities and start private initiatives for PFAS measurements in serum. If authorities refuse to perform HBM in hotspot despite a high pressure from the local community or public demand, there is the possibility that citizens will organize themselves and finance their ‘own’ studies (e.g., through crowdfunding). Private initiatives (or from citizen groups) on PFAS serum analyses are popping up; commercial PFAS self-sampling test kits are on the market; some research labs also offer their lab capacity for analyses on behalf of private initiatives or from citizen groups. Such results receive media attention and serve as political pressure.

- The private initiatives (or from citizen groups) on PFAS HBM cover in general a smaller number of participants (e.g., tens instead of hundreds), which might be valuable to get a first insight on ranges in exposure levels; however, results cannot be considered as well representative for the affected population, since this would require a recruitment scheme reflecting the variance in age groups, geographical range, gender, duration of residence in the area, etc. This is not possible on a limited number of samples. Hence, these initiatives risk biased results.
- One should not criticize or offend too much such initiatives; however, it is wise to act pro-actively and support the initiators of such studies by providing guidance for adequate interpretation and framing of the results, quality check of the results reported by the labs, and also to support local health workers (general practitioners) with similar materials as would be the case when performing a HBM study set up by authorities.

HBM studies are by preference financed by the responsible local, regional or national authorities or foundations. Authorities can consider claiming back the costs from the polluters (‘polluters pay’ principle). In any case, the role of industry in financing should be transparent, and should not prevent to perform research in an independent way.

5.2.2 Points of attention

5.2.2.1 Environmental mapping as starting point

Prior to design a PFAS HBM campaign in a hotspot, it is advised to perform PFAS profiling in environmental media or emission records is a first step. On the one hand, assessment of PFAS in environmental media will help to get insight in relevant exposure routes and thus likely high exposed populations; on the other hand, information on the types and levels of PFAS in the environment is helpful to select the relevant biomarkers of PFAS for human biomonitoring.

5.2.2.2 Quality criteria for analysis

It is advised to pay attention to quality criteria of PFAS serum analysis, including LOQ/LOD, reported uncertainty on the data, number and types of PFAS, and whether linear and/or branched PFAS compounds are reported. Quality is important to allow a proper comparison with results from reference populations, and in view of comparison with human biomonitoring guidance values (Apel et al., 2020) and of course when using the results for research purposes.

5.2.2.3 Biobank as historical archive

When performing a HBM study, one must make choices on biomarkers of exposure and of health effects to measure. This is dependent on the research question(s), budget constraints, type and volume of sample (human matrix) and availability of analytical techniques. However, the interest in biomarkers of exposure and health effects might expand and change as our knowledge advances, and the techniques to analyze more PFAS advance. In order to anticipate this, it is highly recommended to perform biobanking of biological samples for future needs (= opportunities for future research, since it avoids the need to re-sample). This requires biobank infrastructure, monitoring of the preservation process, and informed consent of participants.

5.2.2.4 Control groups

When reporting HBM results in a PFAS hotspot, it is recommended to compare the results against a control group. Given the widespread use of PFAS within the last decades, PFAS have become ubiquitous in our environment all over the world, so that also populations living outside hotspots ('background exposure' in the general population) have also PFAS in their serum. Nevertheless, around hotspots PFAS serum levels might be much higher than in the general population. There are two ways to compare with background population: the first option is to initiate in parallel to the hotspot, a HBM in a control group in the neighbourhood outside the influence zone of the PFAS contamination, and hereby selecting study participants with matching profiles as the one in the PFAS hotspot. Alternatively, one can rely on general population monitoring results (e.g. overview of PFAS monitoring in general population can be consulted on the HBM4EU dashboard: https://www.hbm4eu.eu/what-we-do/european-hbm-platform/eu-hbm-dashboard/), provided that the characteristics of the populations groups (age, gender, specific subpopulations) are fairly comparable with the characteristics of the investigated hotspot study.

5.2.2.5 Investing in questionnaires

When performing HBM in a PFAS hotspot, it is advised to collect ancillary information via questionnaires to be able to draw conclusions regarding exposure determinants and to collect information on confounding factors. Information on determinants of exposure can be useful to design a proper remediation or exposure reduction strategy. Information on confounding factors is needed to interpret exposure-effect associations.

Questionnaires should at least include questions related to demography, age, gender, where participants live and work and for how long, and exposure related questions related to all suspected routes of exposure (local food, water, soil and dust, air, use of products, etc.). Depending on the research question, it might also be useful to include questions related to the health status of the participant.

The difficulty relies in developing questionnaires in layman language that are not too long to complete by participants, and at the same time provide sufficient, useful information for proper data analysis and interpretation.

Experts in this network recommended to design common questionnaires to be used in various hotspots across Europe. Harmonized questionnaires for general population have been developed under HBM4EU, including questionnaire for PFAS[1]. However, no such common questionnaires tailored towards PFAS hotspots has yet been designed. Such common questionnaire could form the basis, but then should be adapted to the local situation (e.g. including a question about whether or not the participant works/worked at the local PFAS production plant will be needed in one hotspot but not in another, questions can be adjusted based on relevant environmental data,...). In the meantime, it might be useful to contact researchers of conducted PFAS hotspot studies and ask whether they are willing to share the questionnaires they used in their studies. Contact details can be provided by this working group.

5.2.2.6 Beyond PFAS: exposure to other chemicals

When considering PFAS human biomonitoring in a hotspot (and searching for associations with health effects) it advised to investigate the need for addressing multiple exposures (not only PFAS). Hotpots are often situated around industrial sites with potentially other chemical pressures.

[1] Harmonized questionnaires available at: ONLINE LIBRARY – HBM4EU – science and policy for a healthy future

Only looking at PFAS could miss part of the chemical exposure, and leading to bias in PFAS exposure – effect associations. Mapping of sources of other chemicals, and identification of presumably other relevant chemicals is recommended for this purpose.

5.2.2.7 Selection of (bio) markers of exposure

The use of human biomonitoring as a tool to assess exposure should be regarded in view of the (toxicokinetic) profile of the prevailing PFAS compounds. For legacy PFAS compounds (e.g. PFOS) with a long half live, analyzing serum is an adequate tool; however new, short chain PFAS compounds (replacing often legacy PFAS in current applications) may be less detected in serum; however this should not be regarded a priori as absence of exposure; low concentrations of a chemicals with short half-lives might still reflect (past) high exposures. For substance with shorter half-lives, complementary tools to assess exposure can be considered (e.g. analyzing in other matrices such as urine, or presence in environmental media in combination with modelling).

5.3 Guidance on risk communication

According to the WHO (www.who.int/emergencies/risk-communications) risk communication in situations of public health emergencies includes the range of communication capacities required through the preparedness, response and recovery phases of a serious public health event to encourage informed decision making, positive behaviour change and the maintenance of trust. Some of these aspects can be translated to risk communication in human biomonitoring initiatives in hotspots. Further, the experiences in the European hotspot cases that were provided through the inventory provided useful input for the current guidance document.

Centrally in the process of risk communication is the design of a **communication plan**. This plan should describe the different steps, both for the communication of collective and individual results and include the following aspects with regard to communication: When? Who? To whom? How? What?

In each step, it is important perform a **context analysis** and adapt the communication process accordingly. Hence, an inherent part of the communication plan is to document the strategy behind the communication by defining the expected outcomes and motivate the approaches to reach these outcomes.

In the current guidance document, the different phases of a communication plan are described and recommendations are done. It is important to stress that there is not 'one ideal' approach, but 'several good' strategies can be applied. Choices in the communication strategy depend among others on the specific study design (e.g. HBM as scientific study or HBM as a tool to merely assess exposure), local factors (e.g. country specific attitudes, engagement of social movement groups), the available resources, etc. The decisions on these different choices can be an inherent element of the communication strategy, and are therefore important to be documented.

In the communication it is important to position the HBM strategy and results in the broader context of the hotspot. A communication toolbox could bring together all information: How was the hotspot identified? Why HBM? What other data are available (e.g. environmental data) and how are they communicated? What other actions are taken? All these context elements will have an impact on the communication strategies that are followed for the HBM.

5.3.1 Communication of collective results

WHEN? The communication plan should run **throughout the entire process**. It is not only a matter of presenting a report at the end of the study. It is important to build trust and tell the story along the way. In the first place, because PFAS and HBM are such complex and difficult themes, and by planning the communication step by step the information can gradually be presented to the stakeholders in a tailored way. As such, the audience becomes familiar with the content and has the opportunity to comprehend complex results. Further, by communicating over time, trust can be built. When a hotspot is discovered, there often are strong emotions in the population. People are worried, angry or confused. At this stage, conflicting information can come via different channels. Therefore, it is advisable that scientists and policy makers take the lead in the communication and share all the available information from the start. This should happen in a very transparent way, thus taking sufficient time to explain each phase of the study, and more specifically the rationale behind the decisions, the uncertainties in the process and the expectations (what can the study tell us and what can't the study tell us?). A participatory process with the involvement of stakeholders and local actors from the start of the project can have a large added value for the research itself since it allows to address specific concerns and to take into account local elements that are often not known by general scientists. Moreover, it helps to build confidence in the study results, to get support for policy actions and to take responsibility for implementing the actions by the public and the community.

WHO? It is important to define in advance the roles of the stakeholders that are responsible for the communication. Therefore, based on the context information, a stakeholder mapping can be done, so that the communication plan can be built with complementary roles for the different partners. **Scientists or researchers** are responsible for the communication of the different aspects of the study in a neutral and objective way. With respect to study design, they report and frame the results against the current scientific knowledge (e.g. with respect to sources of PFAS, routes of exposure, health impact). It is important that the research team is multidisciplinary (e.g. toxicologists, epidemiologists, medical doctors, statisticians, chemists, sociologists, etc.) and that each discipline is involved in the communication. **Policy makers (politicians and/or administrations)** are responsible to use this scientific knowledge and translate it into policy impact and hence communicate on the policy measures that should or will be taken in the future. **Local stakeholders** (GPs and other health workers, local environmental officers, environmental and social action groups) also have a role in the communication process. Their role in the communication process may be less prominent in the beginning since they often lack specific expertise with respect to HBM and/or PFAS. But, informing the local stakeholders should be one of the targets in the communication plan, and as such local stakeholders can be actively involved as point of contact throughout the study. In the stakeholder mapping, a role for **Industry** in the communication is expected. Industry often has its own data; there are expectations of civilians and politicians with regard to transparency, and they can help to define realistic actions. Therefore, it is important to engage industry in the communication process. Not only the enterprise that is linked to the source, but also other industries in the same region. In the European examples of PFAS hotspots, there is little experience with involvement of industry. However, an open and transparent communication of the industrial partners would be a mutual benefit to all stakeholders involved. When industry is involved according to the polluter pays principle, they can communicate on this aspect, without interfering actively in the research process. They can, however, be actively involved in the actions for remediation.

TO WHOM? In the communication plan, the target groups should be defined. This may vary according to the type of study that is done (environmental measurements, exposure biomarkers and/or health effects). The **participants** of the HBM study should be treated as ‘privileged witnesses’; they should be the first to be informed on the collective results of the study that they participated in. Other important stakeholders are **local authorities** (major, governor, …) and **intermediaries** (general practitioner and other health workers, environmental officer, …). These local stakeholders can be informed before the **general public** and the press, so that they have the opportunity to comprehend the results and prepare their own communication strategy.

HOW? Communication should be done via different channels and at different levels. A **website** is a perfect tool to centralise all information. Information should in the first place be presented at a laymen’s level, so that it is useful to the general public. Fact sheets and infographics are good formats to present complex information in an accessible manner. It is the responsibility of the scientists to translate complex information to a format that is comprehensible for a large target group. The key points should be expressed at laymen’s level so that the messages are not translated wrongly. Additionally, the website can also contain more specialised reports, e.g. scientific background documents and detailed research reports. This information is not only for professionals, but also for an interested civilian. Environmental or social actions groups often have members that want to deepen their knowledge. Further, the website can contain links to trustworthy instances to provide international information, e.g. HBM4EU, EEA, WHO, etc. Research groups can also make use of **social media**, but should foresee enough personnel to keep the information up to date and to be able to respond timely. **Information meetings** – both physical or online – can be organised to inform the population and/or the intermediaries. For some stakeholder groups, e.g. health workers, it might be interesting to organise trainings in order to empower them to communicate with the public. Finally, press releases and press conferences are a channel to reach the general public. **Scientific publications** are important to distribute the results to the international community in a peer reviewed way.

In a crisis situation, the communication channels are often mobilised on a very short notice. Adjustments along the way are necessary and possible. Also, it is important to retain the available communication after the crisis. An important point to take into account is the (sometimes) more limited access of vulnerable groups to digital information (older people, socially vulnerable groups, …). This can be solved by using a mix of communication channels, such as digital and paper materials, written and spoken materials, ... whilst increasing the reach of all target groups. Regardless of the channels used, the key messages should be quick, clear, simple and catch the attention of the target group.

WHAT? Group results of HBM surveys are an important trigger for policy actions. More than environmental measurements, the group results of serum PFAS in a hotspot area or the associations between exposure and health at a local level, are important drivers to visualise the problem, raise awareness, be a step into the direction of changing consumer or lifestyle behaviour or installing remediation actions. The principle of 'pollution gets personal' also works on a group level. For example, the percent of the population that exceeds a health-based guidance value (HBGV) or the differences between levels in a hotspot area compared to background levels clearly demonstrate the scope of the problem that should be tackled. Contrary to individual population, the population data can be used to interpret an exceedance of HBGV in relation to the risk of disease. Exceedances of HBGV on the population level gives information about that the exposure is too high from a societal point-of-view and should be reduced if possible. Apparently, most health communications tend to overemphasize uncertainty, dismissing legitimate reasons for concern in affected communities (Ducatman et al., 2022). Indeed, it is a challenge to translate scientific results into clear messages with a right equilibrium between clear and scientifically correct results (*what can we learn from these results?*) and unresolved uncertainties. Health communication should raise public awareness without engendering undue fear.

The sequence of communication may differ according to the local situation. E.g., in some cases, there is a high pressure to take immediate action, and therefore preventive actions (no regret measures) are already taken in the phase before the HBM studies. In other cases, this would not be acceptable, since the population would perceive this as an alarming signal and will only accept policy measures that are based on measured data from the own region. Again, there is no 'right' or 'wrong', but rather a case by case approach which is maximally based on the pro-active anticipation. Stakeholder groups such as press, environmental or social movement groups or politicians may also have impact on the decisions.

Data are often made available on an aggregated level to a broad public, e.g. in a dashboard. In this way, there is also an option to link HBM data to data of different sources.

Scientific results are often available for future research. This should also be a transparent process. The management of the data is the role of an advisory board who acts as a gatekeeper and guarantees that there is no conflict of interest and that the rights of the participants are guaranteed. The website is a good tool to communicate on the results of secondary studies with data from HBM projects.

5.3.2 Communication of individual results

WHEN?

A first question is whether or not individual results should be communicated. The general principle is that participants have the **right to know**, but also have the **right not to know**. Therefore, in all cases there should be a procedure for participants to receive their personal exposure and health data. At the same time, participants should always be in a position to object against the communication of individual results, e.g. via the informed consent form.

Irrelevant of the choice of an individual, most research groups decide to foresee a standard procedure for the communication of the individual results. The selection of which biomarkers are communicated individually should happen in advance in a transparent and motivated process. Also here, it is important to define a strategy and to motivate the choices that are made in a transparent way. The experiences in the European hotspot case in this respect are diverse. As the local context can be very different, the communication process is context driven. This depends on the level of experience, the pressure of social action groups, the prior knowledge of civilians, the (active) involvement of medical professionals, etc…

With respect to communication of personal results, all countries in the network agree that results should be communicated only if there is a **clinical relevance**. For health data (e.g. serum cholesterol, hormone levels, etc.) the clinical relevance is clear. For parameters that reflect early biological effects or changes in tissue function or structure (e.g. comet assay, gene expression, etc.) there is consensus that these values are not interpretable on an individual level; most research groups advise not to routinely communicate the individual values (although the right to know remains, and thus participants can actively request their own value anyway). For the biomarkers of exposure (PFAS in serum), the decision on whether or not to communicate individually is diverse. Some countries consider the values not suitable for individual communication as they are intended for research purposes and should therefore only be used on a group level. They argue that there is no added value in knowing your own individual serum PFAS level, since there are no strategies to individually lower your value. Communication of a high value will lead to individual stress, which might be worse than the PFAS value itself. In addition, currently there is no validated treatment available. Therefore, these countries argue that only the group results should be used as a basis for preventive remediation actions, and all individuals should receive the same recommendations, irrespective of their personal value. Other countries decided that communication of individual serum PFAS values is an essential part of the study. Often, in hotspot areas with a crisis situation, the demand of civilians to know their personal value is very clear, and hence not reporting is not an option. In these cases, it is extremely important to provide a good risk communication strategy, together with adequate background information and with the necessary individual support and aftercare (see further: What?).

The **period** between sampling and communication of biomarker values is usually long since individual data are mostly compared with group results, and this can only be done at the end of the study. This timing should be communicated very transparent at the start of the study. Also, in order to keep participants involved despite the long waiting time, researchers could communicate about the progress of the study. In case that clinically relevant data are measured (e.g. hormone levels, liver function tests, etc…), a procedure should be foreseen for immediate tracking of alarming values, together with a risk communication strategy by a medical doctor, e.g. communicate the results to the general practitioner, to the participant itself or to the parents in case of minors. Participants should be informed in advance about this strategy.

WHO? Communication of individual results should be organised by the **research group** who performed the blood sampling and has received the contact details of the participants via the signed informed consent form. Both health data and exposure data should be considered as clinical data and should be communicated under the supervision of a **medical doctor** with relevant experience in field of environment and health.

TO WHOM? Individual results should always be communicated **directly to the participant** or the parents of the participant in case of minors. Optionally, the results can also be communicated to the general practitioner, at least when the participant gives consent.

HOW? Most countries use paper letters to report back results to the participants. This allows to work with a combination of text and tables, but also to include fact sheets, check lists or infographics. This way of working also ensures that groups with a low digital literacy are not excluded. A limited number of the research groups has experience with digital communication tools to report back. This allows to present the information in a more layered manner, e.g. by using click through menus (from very simple messages to more complex, scientific information), by using tags or pop-up menus to explain difficult concepts or even by including short educational videos. The use of a digital report back tool also allows to make an easy connection with the group results and the general background information on PFAS on the study website. Reporting back individual results should also be accompanied by information sessions, both in a generic way (information meetings for participants and/or the general public) and through a personal approach (individual consults, see further under 'aftercare').

WHAT? When designing a strategy to communicate individual results, different aspects should be considered.

The individual serum PFAS values are reported as concentrations. Since several PFAS can be expected below the detection/quantification limit, the meaning of a limit of quantification or a limit of detection should be explained clearly at a laymen's level.

In order to support the individual in the interpretations of the personal serum PFAS value, it is important to compare the individual value to a reference value. The different countries deal with this in different ways. Almost all countries compare the individual result to the group levels, often the median of the hotspot area, and sometimes also the 90^{th} or 95^{th} percentile of the group. For PFAS in serum, different human biomonitoring guidance values (HBM-GV) are available (e.g. HBM-I / HBM-II values of the German HBM commission; EFSA HBGV). Some countries believe that these HBM-GV can only be used on a group level, and therefore do not use them in individual communication. Other countries use the HBM-GV to define the risk categories and give appropriate tailored-based advise for the different risk groups. An extra argument to use HBM-GV in the individual communication is that there are different HBM-GV available in the international scientific literature, and interpretation by unexperienced users may lead to false conclusions. In the workshops that were held to prepare the current guidance document, there was consensus that the EFSA HBGV of 6,9 ng/ml for the sum of PFOA, PFNA, PFHxS and PFOS (www.efsa.europa.eu/en/efsajournal/pub/6223) is only suited for group communication and cannot be used for individual communication. The HBM-I and HBM-II guidance values for PFOA and PFOS of the German HBM commission (Hölzer et al., 2021; Schümann et al., 2021), however, are suited for individual communication, although not all countries decide to use them in this manner. Therefore, the choice and application of the HBM-GV can best be done by expert scientists, with a clear and transparent explanation on the interpretation of the result. All countries agree that the HBM-GV are not intended to determine the risk of having a disease in the future at an individual level; it is of major importance to explain this in the communication with the participant. The meaning of 'being at risk' and the associated health risk for the individual must clearly be explained at an intelligible and laymen's level. Communication of individual results, whether or not in combination with a HBGV, should always be accompanied by an **action perspective** for the participant. Information on possible sources and exposure routes can empower the individual to reduce exposure in the future. This information can be offered in a general way, or can be made more personal by working with a check list. In any case, it is important to stress that personal preventive measures can be applied, but it is not the responsibility of the individual civilian in its own. The results of a HBM study are mainly intended to provide input to policy makers and researchers to allow them to design focused actions on a collective scale, e.g. remediation measures, legislation, awareness campaigns, etc. This bigger picture should also be addressed in the communication and people should be informed about the actions taken on a higher level.

An important phase of the communication process is the **aftercare** for the participants. Ideally, consultations by a trained medical doctor with expertise in the field of environment and health should be foreseen in the days/weeks after the delivery of the personal results. There also can be a role for the local community workers, such as a medical environmentalist, a district nurse, etc. They can support civilians by assisting them in identifying sources in the personal environment and thereafter leading them to the appropriate communication channels (e.g. provide contact details of laboratories for soil analysis, give general advise on hygiene measures, etc.). Some participants, however, may prefer a consult by their own general practitioner (GP). Therefore, local GPs in a hotspot area should be informed about the study, the type of results that are communicated and the recommendations for follow-up. In case clinical guidelines are applied, it is important to include clinicians with relevant expertise in environment and health, and specifically also with PFAS. Some good examples already exist. In Denmark, the national health board has published guidelines for GPs (www.sst.dk/da/udgivelser/2022/helbredseffekter-af-pfoa-pfna-pfos-og-pfhxs). Also in the U.S., the Centers for Disease Control and Prevention (CDC) published a guidance document for clinicians (www.atsdr.cdc.gov/pfas/docs/clinical-guidance-12-20-2019.pdf).

Some good examples of communication websites for PFAS in hotspots are given below:

- Italy, Veneto case: https://www.regione.veneto.it/web/sanita/pfas
- The Netherlands, Dordrecht case: https://cms.dordrecht.nl/Inwoners/Overzicht_Inwoners/Dossier_Chemours_en_DuPont
- Denmark: PFAS Sundhedsstyrelsen: https://www.sst.dk/da/Viden/Miljoe/Miljoe-og-sundhed/PFAS
- Belgium: PFAS Vlaanderen https://www.vlaanderen.be/pfas-vervuiling
- United States: Silent Spring Institute https://pfas-exchange.org/resources/
- UN environmental program: https://twitter.com/UNEP/status/1505618756629942279 (not working on explorer)

6 Recommendations

6.1 Knowledge gaps and research needs

6.1.1 General

More research is needed to investigate the impact of PFAS exposure on health at exposure levels typically found around PFAS hotspots.

Health impacts related to PFAS exposure has been investigated in several epidemiological studies (the general population, occupational populations, populations living in PFAS hotspots), animal studies and in vitro studies. Several comprehensive reviews have been published (ATSDR, 2021; EEA, 2019; EFSA, 2020).

At present, we have a considerable amount of exposure and health data from background exposure level populations (although sometimes with conflicting results on health effects), and some data from studies at high exposures, but we lack information throughout the broad exposure ranges found at hotspots. And that information can only come from hot spot populations.

There remain several research gaps, and thus questions for individuals living at PFAS hotspots remain unaddressed. When considering a HBM study in a PFAS hotspot, it is therefore strongly advised to do exposure HBM survey within the context of a research project **to fill gaps in our knowledge concerning PFAS exposure and the associated health effects. Research gaps are:**

- Impact of less studied PFAS compounds (which are likely to occur at various hotspots). The majority of the studies have reported health effects related to PFOA and/or PFOS exposure. It is advised to measure several PFAS, selection should be in line with suspected PFAS profiles in the environment (individual compounds, total PFAS, extractable organofluorine)
- Impact on vulnerable groups, and/or in combination with impacts on less studied health effects/groups (e.g. immunological response, osteoporosis, endocrine disruption, cancer, thyroid disease, alteration of thyroid hormone levels, impact on the next generation: fetal programming, etc.). Examples of vulnerable groups to consider: children, pregnant women, elderly, chronically sick people. Latency (lag time between exposure and effect) is an important point of attention when selecting subpopulations to study
- Impact at exposure levels above background- general population and below occupational exposure, i.e. levels of residents around PFAS hotspots.
- Good studies are lacking where relations between cumulative exposure from drinking water, food and body burdens are available. Such studies are needed as basis for exposure model development

Guidance for study design, selection of biomarkers for exposure and effect cannot be given in general terms but should be tailored towards the specific research questions of a study. Hereto, one can use the list of effect markers for 1st priority compounds including PFAS (see Deliverable 14.2 of HBM4EU: Mustieles et al., 2018).

The nature of the research questions also affects the type of study that is preferentially performed. Cross-sectional studies can serve for survey purposes, while research questions on potential health effects of PFAS in a hotspot region prefer a follow-up design with a sufficient sample size and exposure gradient.

6.1.2 Research regarding interventions to reduce exposure

Residents around hotspots with elevated to very high PFAS serum levels are often seeking a treatment to accelerate the reduction of their PFAS body burden. However, currently no validated clinical treatment is available. One can empower the individual to reduce exposure by supplying clean water (in case drinking water is a relevant source of the contamination), by providing information on PFAS sources at the local setting (depending on the local situation: local foods, soil, dust, air) so that they can avoid contact with these sources to reduce exposure. Maximum exposure reduction should be recommended to anyone living in a hotspot area, including those with a lower PFAS value (preventive action). A gradient in recommendations is possible (tailored approach). This information can be offered in a general way or can be made more personal by working with a check list on personal actions that can be taken. In any case, it is important to stress that personal preventive measures can be applied, but it is not the responsibility of the individual civilian on its own. One should be realistic in terms of achievable reduction potential given the long half time of some PFAS compounds. Several PFAS compounds have half-life times of more than 5 years, hence patience is needed to see the effects of reducing exposure.

Methods to accelerate exposure reduction in a more active way are currently under investigation. The use of cholesterol-lowering resins (e.g. cholestyramine) is currently under investigation on a panel of volunteers in the Korsør hotspot (Denmark). Cholesterol-lowering resins work as anion exchangers, which act by binding the bile acids in the intestines, thus increasing their excretion. Bile acids are synthesized from cholesterol and by increasing bile acid excretion via faeces, the agent increases the conversion of cholesterol and lowers serum levels. Cholestyramine also binds PFAS which are excreted via the bile and to a large extent reabsorbed, similar to bile acids (entero-hepatic cycling). As a result cholestyramine also reduces the body burden of PFAS. This intervention is currently under investigation in a research phase. Once this intervention is completed, the effectiveness of the intervention should be validated in further studies. Further research is also necessary to elucidate when to consider offering this treatment to (vulnerable) people with high PFAS serum levels, including when the benefits of reducing PFAS levels outweigh the potential negative effects of taking this medication. This could be in high-risk populations e.g. young women with high PFAS serum planning a pregnancy.

More invasive methods (repeated bloodletting) have been considered in the past as a way to accelerate PFAS elimination but are considered as non-ethical and a very questionable balance between health benefits (PFAS reduction) and negative effects of bloodletting for this purpose.

6.1.3 Advancing exposure modelling

One of the arguments to use HBM as a tool to assess exposure is that it overcomes potential shortcomings of missing exposure routes and sources based on modelling. However, eliminating these shortcomings by further developing of PFAS exposure models is highly recommended. Once we have adequate and reliable models, they can offer a faster and cheaper alternative compared to setting up a HBM campaign. Modelling has been proved as a valid tool in some hotspots (e.g. in Dordrecht, PFOA exposure caused by emissions to air), and should be extended to cover as well more complex and diverse exposure sources and routes, and other PFAS. Human biomonitoring data can help to further develop and verify such models. Thus, HBM data from hotspots can help to facilitate modelling exposure in other hotspots (and reducing the need for HBM in other cases).

6.2 Need for collaboration in research projects across hotspots in Europe

There is an opportunity and need for more collaboration in health research at PFAS hotspots across Europe. Collaboration will create the opportunity to gather more harmonized and comparable data to be able to perform analyses on larger datasets (number of study participants) and with greater exposure contrast, resulting in a higher study power. This could resolve the limitations when performing exposure-health studies in single hotspots with a limited sample size. Studies based on limited sample sizes are likely not able to detect statistically significant effects by lack of power.

As a first step, it is advised to make ***a common basic protocol for studies in hotspot populations, including the design of harmonized questionnaires (cfr. harmonized questionnaires for general population developed under HBM4EU, including questionnaire for PFAS[2]).*** Setting up of aligned PFAS hotspot studies across Europe has the benefit in coverage of a wider range of exposure levels and profiles (PFAS types and exposure routes), and analyses of such pooled datasets will give us a stronger basis for investigation of exposure – effect associations than via single hotspot studies, especially to make valid scientific statements about seldom health effects.

6.3 Policy recommendations

Environmental PFAS contamination at several hotspots across Europe has led in several regions in Europe to policy crisis and distrust of citizens in authorities and industry due to failure of governance and environmental management. Improving existing policies and setting up new policy actions is required to reduce and prevent exposure at hotpots. Hereto, collaboration on EU level would be beneficial (e.g., setting air quality guidelines, emission limits, soil guideline values, emission registers, limit values for food items), both at policy levels where regions are responsible as well as at national or European policy fields. The information on PFAS hotspots is currently considered in the proposal for a European ban on PFAS (PFAS restriction proposal; joint action between the Netherlands, Denmark, Germany, Norway and Sweden).

Regions without yet identified PFAS hotspots can learn from regions on identification of hotspots, since it is not very likely that countries have no PFAS hotspots, given the widespread uses; rather PFAS hotspots are currently unidentified in some regions and countries (see section 5.1) .

We should strive further, via collaboration between science and policy, to shift towards a sustainable society (zero pollution) where no crisis similar to PFAS are happening in the future. Hereto, it is recommended to shift from a crisis management to a preventive policy. Such a preventive policy should not limit only to PFAS, but also to other harmful and persistent substances..

[2] Harmonized questionnaires available at: ONLINE LIBRARY – HBM4EU – science and policy for a healthy future

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Annex 1: inventory of PFAS hotspots

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Upssala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
key criteria										
data available on environmental pollution and residents' health conditions	the PFAS contamination in the environment (soil, grondwater, biota: bird eggs, biopods) around 3M was known by scientific communities since > 10 years; no information on the resident's, heatlh conditions was available	Exposure from municipal drinking water highly contaminated by primarily PFOS and PFHxS. Source of exposure was leakage of AFFF-foam from a military airport. The start of exposure is not known but AFFF-foam was in use at the airport since the mid 1980's. After end of exposure, pregnant women were invited to participate in a prospective cohort with biobanked biological samples, questionnaire data and data from medical charts. Children will be assessed for to neurodevelopment, bone mass density and puberty onset.	PFAS contamination in drinking water provided to the local airport in Arvidsjaur; source of contamination is firefighting foam. When the contamination started is not clear. Only airport workers were affected. PFAS levels in drinking water and in worker's blood is available. No heatlh data from the airport workers.	Drinking water levels, PFAS serum levels in first-time mothers and their children, questionnaire information	Contaminated private/municipal drinking water	The contamination was originated by industrial emissions, primarily from a chemical plant that has been active since 1968. Nevertheless, the contamination was discovered in 2013, when data on PFAS concentrations in groundwater, surface water,and drinking water were available. No information on the resident's, health conditions was available.	In the frame of monitoring project POPMON potential hot spots should be identified - POPMON I: identification of POPs hot spots including PFAS; POPMON II: investigation of PFAS contamination case: elevated PFOS levels and other PFAS (at lower levels compared to PFOS) have been detected in Lebring-St. Margarethes drinking water between 2016-2018 and it was assumed that the water conservation area may be affected	The PFAS contamination in Korsør was found by coincidence, in connection with an examination of medicines in wastewater samples. These tests showed a high level of PFAS (Mainly PFOS and PFHxS). Source tracing was conducted. The pollution was found to originate from the firefighting training facility in Korsør. The firefighting training facility is situated on a small hill above a meadow used for grazer cattle. Below the facility, a drainage channel runs through the meadow. High amounts of PFOS was found in drainage channel. PFOS was found in grass and soil near the firefighting training facility and the drainage channel. As the area isn't used for extraction of drinking water, no pollution of drinking water was found. The contamination is therefore in soil, water, grass, and the grazer cattle (veal). Link to the municipality's website: www.slagelse.dk/PFOSkorsoer 2020 - Korsør wastewater discovered PFAS Early 2021 - Source tracing to fire extinguishing foam used at a firefighter training facility. Further investigation – pollution of nearby meadow grazed by cows from the local cow grazer association. March 2021 – high concentrations of PFOS were discovered in the meat. The local municipality contacts the national health authorities. April 2021 – involvement of the	Before this study, no measurements were taken in the area or in the blood of local residents. In 2016, a risk assessment was conducted by RIVM where they investigated to what extent PFOA was released into the environment from the factory DuPont/Chemours in Dordrecht between 1970 and 2012 and what possible health effects this has had on local residents. These were model calculations and not measurements.	PFAS-contamination drinking water, fish, surface water (and soil)

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								Regional Clinic of Occupational and Environmental Medicine.		
(presumable) main routes of exposure	consumption of local foods (mainly eggs); contact with soil and dust, and groundwater. Municipal drinking water is not a main sources (very low levels of PFAS in tapwater); consumption of meat products and fish is not likely a main source of exposure given the catchment (urban environment, no fishing activities or probably no local animal farms)	Drinking water.	Through drinking water	Drinking water	Drinking water	Municipal drinking water was identified as the main source of exposure, but additional exposure was due to the use of drinking water and irrigating water from private wells.	Presumable: regional fire fighting training sites, metal processing industry facility and (legacy) waste disposal site may contaminate the drinking water sources and contaminate the water sources that are used for irrigation purposes	Consumption of contaminated beef from a local cow grazer association in Korsør. Analyzes of meat from the veal showed high levels of PFOS	Inhalation: breathing air contaminated with PFOA (historical) is probably the most important route of exposure. In the past (until 2012) PFOA was emitted into the air by the chemical factory DuPont/Chemours in Dordrecht. Consumption of contaminated drinking water is not a main source given the very low levels of PFOA in Dutch tapwater.	consumption of drinking water, fish from contaminated rivers/lakes
public concern	the authorities were aware of the contamination since several years, but decided in 2017 not to communicate to the public because at that time they considered that there was no concern for public health (based on the health based reference values available at that time); the attention for public health was not raised before May 2021. Around may 2021, the case was brought to the public attention by a pressure from a concerned citizen, who raised concern for health risks due to soil excavation and transport of PFAS	Primarily in relation to breastfeeding.	The airport workers were concerned about the exposure	There has been some media but no big concern in the public	A lot of publicity in the local areas. Some concern from the public.	After the discovery of the contamination, general population was informed by health care trusts and by the web site of the Veneto Region. The public concern was very high and received high media attention.	Monitoring initiated by federal authorities from 2016-2018 showed elevated PFOS levels in the drinking water. Other PFAS have been detected in the drinking water as well although at lower levels compered to PFOS. Exclusively groundwater is used for drinking water purposes in the area. The identification of the source of PFAS contamination is of high concern to be able to minimize the exposure. If the elevated drinking water levels cause elevated PFAS body burdens is still unknown.	Even though PFAS has not had much public attention in Denmark before 2020, the monitoring of PFAS in the environment has been reported since 2007. **Bold text: Actions of the Danish authorities** Underlined text: The Korsør case Italic text: *International actions* Timeline - Denmark and PFAS. - 2001, 22nd of May: Adoption of The Stockholm Convention. Agreement to start to phase out selected Persistent Organic Pollutants (POP). *- 2004, 17th May: The Stockholm Convention comes into force.* - **2004: PFOS on the Environmental Protection Agency's (EPAs) list on unwanted substances.** - 2**006: Outphasing of PFOS in**	In September 2015, reports of PFOA emissions around a factory of the chemical group DuPont in the American city of Parkersburg (Western Virginia, C8 study) led to concern in the Netherlands. Especially around the factory of DuPont/Chemours in Dordrecht concern was raised about emissions and the possible effects of PFOA by DuPont/Chemours. Questions were asked about this in the House of Representatives. In response to these questions, the State	Drinking water had been contaminated by the extensive application of soil conditioner/fertilizer on agricultural areas. The fertilizer had been polluted with PFAS (presumably originating from disposal of industrial waste). Drinking water contamination (> 500 ng PFOA/l) began presumably between 2002 and 2004, was detected in 2006 and was published in May 2006. In July 2006, the waterworks of Moehnebogen installed activated-charcoal filters, which efficiently decreased PFC concentrations in

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	contaminated sites in that region; the EFSA TWI published in 2020 (4.4 ng Σ PFOA, PFOS, PFHxS, PFHNA/kg bw) played an important role in the debate. The public concern was very high due to high political attention to the case.							**firefighting foam in Denmark**, due to increased focus on Persistent Organic Pollutants and PFAS in EU, REACH-regulation nr. 1907/2006, appendix XVII, no. 53. However, it is still legal to use residual stock. - **2007: EPA: Report from Denmark's environment surveys** (Danmarks Miljøundersøgelser, DMU) 608/2007 on PFAS (NOVANA screening study) - *2010: EU recommendation to member states t*o ensure "monitoring of PFAS in food". - **2011: The Danish Environmental Protection Agency makes random sampling on meat and fish.** No findings of concern. These tests are repeated every following year. - **2011: EPA: Prohibition on the use of PFOS in firefighting foam.** - 2014: EPA: List of Unwanted Substances – Observation of PFAS in Denmark. - 2015, June: Report by National Food Institute, DTU: "Chemical contaminants 2004-2011- Food monitoring 2004-2011" page 116-119 describes PFAS. - 2**016: The Danish Ministry of the Environment and Food maps the industries using PFAS in Denmark.** - **2018: EPA sets new regulations for drinking water with the limit value for PFAS on 0,1µg/L.** - **2018: The Danish Regions' Environment and Resources publish: "Handbook on investigation and avert PFAS pollution".** - 2019, Fall: Wastewater samples from Korsør are sent	Secretary of the Ministry of Infrastructure and the Environment (IenM) instructed RIVM to investigate whether the model calculations from the risk assessment in 2016 correspond to the serum values measured in the study.	drinking water. HBM study started between September and October 2006. German drinking water commission.

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								to the Lund University of Sweden, to be tested for medicines/pesticides as a part of an EU project. - 2020, Marts: Wastewater sample results come out with high levels of PFOS. - 20**20, 1st of June: EPA: Prohibition on market food contact materials of paper and cardboard in which per- and polyfluorinated alkylated substances (PFAS) are being used, unless a functional barrier is used in the product, thereby avoiding migration of the substances into the food.** - 2020, October: Slagelse Municipality informs the Danish Environmental Agency about the test results, The local municipality is asked to conduct a source tracing investigation. - 2020, December: Press release from Slagelse municipality about the high levels of PFOS in Korsør. - 2021, February: Slagelse municipality identifies the firefighting training facility as the source of the high levels of PFOS in the wastewater. - 2021, Marts: Technical University of Denmark´s food institute detects high levels of PFOS in meat from cattle (veal) in Korsør. - 2021, April: Region of Zealand sets up a Task Force group of health professionals at the hospital of Holbæk (Department of Occupational and Environmental Health), to advice the citizens who have eaten the contaminated meat. The members of the cow grasser association are invited to blood sampling at the clinic. - 2021, May: Blood samples of the members of the cow		

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								grasser association are sampled. - 2021, May: Two pregnant women, who will be giving birth soon and are members of the cow grasser association, are the first to their blood test results back. Both have high levels of PFOS in their blood. - 2021, June: EPA: Stricter water quality requirements. The drinking water criteria is now for the sum of 4 PFASs 0,002 µg/L. - 2021, July: The Danish Regions complete mapping of possible contaminated areas. This includes all the firefighting training facilities in Denmark - 2021, August: The rest of the members of the cow grasser association get their results. - 2021, October: The Danish Health Authority form an expert group of PFAS experts, researchers and relevant clinicians. - 2022, 9th February: Based on advice from the expert group The Danish Health Authority publish a report about the health effects of PFAS, and a guide for general practitioner and citizens.		
involvement of stakeholders and local actors	when the HBM started, the main stakeholder were the Flemish public authorities. The local actors (community and local environmental medical team) supported logistics and announcment for recruiting of particpants. However, there was no time to start a full participatory process to design the study	Recruitment and sample collection in connection with routine visits at Maternal Health Care and Child Health Care Services.		Municipal wells are contaminated and the problems are followed/studied by the drinking water producer. Since the discovery of the contamination in 2012 the drinking water has been purified.	Pollution connected to municipal/military airports with the airport autorities investigating pollution. The local counties strongly involved in how to supply clean water. The health care system involved in risk communication	The Regional Prevention Directorate of the Veneto Region involved in the management of the PFAS contamination both local and national stakeholders, in particular the Regional Environmental Protection Agency, the Regional Environment Directorate, the Agriculture Directorate, the Experimental Zooprophylactic Institute of Venice, the health care trusts and	Austrian public authorities, experts from the Environment Agency Austria (EAA) and the Austrian Agency for Health and Food Safety (AGES), local drinking water suppliers	The main stakeholders were Slagelse municipality, who involved the Environmental Protection Agency. After the source of contamination was found, the Danish Patient Safety Authority were contacted. Region Zealand is involved in handling of patients/ members of the cow grazer association. The NGO of cow-grassing association was actively involved with contact on a biweekly basis.	The province of South Holland, the three participating municipalities Dordrecht, Papendrecht and Sliedrecht and the IenM were the main stakeholders. A participatory traject was set up during the study: several consultations were held with a group of members consisting of residents, representatives of	Ministry for Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia, local actors and environmental scientists

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						the central Government, namely the National Institute of Health and the Ministry of Health.			the municipalities, the province and the national government, a representative of Chemours and a representative of the Department of Health and Youth.	
key decision to set up HBM	the key decision was taken by the Flemish ministers of health and environment, in order to respons to the high societal and political concern raised in May 2021; the decision to perform HBM was also an immediately response to evaluate the 'no regret measures' ; i.e. advices the authorities launched to limit drastically consumption of local eggs, crops, groundwater, and other exposure reduction measures (cleaning, hand hygiene, etc).	Research initiative to investigate transplacental and lactational transfer, and to follow the health and general evelopment of the children.		An ongoing HBM-study on first-time mothers in Uppsala from 1996 and onwards is going on and the elevated serum levels in that study was the reason that the contamination was discovered.	PFAS contaminated drinking water was discovered during surveys connected to airports where PFAS firefighting foam is used. HBM was initiated to determing the long-term PFAS exposure in the exposed populations	The indication to set up an HBM study was taken by the Human exposure to environmental contaminants (EUCA) unit of the National Institute of Health, and accepted by the Regional Prevention Directorate of the Veneto Region.	Currently no decision to set up HBM	The examination and HumanBioMonitoring of the members of the cow grazer association was based on a clinical decision based on expert advice (Philippe Grandjean).	The study was commissioned by the Province of South-Holland. After policical questioning in 2016, RIVM conducted a risk assessment to make an estimate of the possible health risks of PFOA in the Netherlands. It was concluded that it is likely that residents living in the vicinity of the DuPont/Chemours factory have had long-term exposure to high concentrations of PFOA. Based on the results of this risk assessment, a targeted sample among local residents was taken to check whether the PFOA concentrations in the blood correspond to the model calculation made in the risk assessment.	supported by North Rhine-Westphalia State Agency for Nature, Environment and Consumer Protection, Ministry of Environment; Ministry of Environment and Conservation, Agriculture and Consumer Protection, North Rhine–Westphalia; HBM was recommended by German Drinking Water Commission
funding	funded the Flemish authorities (Flemish Agency for Health and Care). The Flemish authorities want to claim the cost to 3M	External research grants only - primarily from the Swedish Research Council for the Environment,		Swedish EPA and Swedish Food Agency	Swedish EPA, the health care system, airport authorities	Funded by the Veneto Region, within the framework of the Collaboration Agreement between the Veneto Region and the	Austrian federal authorities	The clinical approach to the case incl PFAS measurements was financed by Region Zealand	Funded by the government: the IenM and the three municipalities involved (Dordrecht,	Ministry for Environment, Agriculture, Conservation and Consumer Protection

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	(polluters pays principle)	Agricultural Sciences and Spatial Planning.				National Institute of Health.			Papendrecht and Sliedrecht).	of the State of North Rhine-Westphalia
research question/h ypothesis	primary question: 1) to **what extent have people living around the 3M site elevated PFAS levels in their serum, and is there an association with distance/orientation of their residence to 3M;** secondary question: does the exposure determinants analyses supports the 'no regret measures' (consumption of local foods, groundwater, hygiene to avoid dust/soil contact), or should these measured be revised (strengthened?, weakened?)	What are the trensfer efficiciencies How does high prenatal PFAS exposure affect the health and development of the child?	Among the airport workers: a) describe the PFAS profile in drinking water as well as in paired serum and urine samples, and b) estimate serum half-lives of short-chain PFAS including PFHxA, PFHpA, PFBS, and PFPeS and the long-chain perfluorohep tane sulfonic acid (PFHpS), along with legacy PFOA, PFHxS, and PFOS, but distinguishin g between linear and branched PFOS.	Study of first time mothers and their children in Uppsala to investigate temporal trends of environmental pollutants. The POPUP-study	Investigation of the relation between PFAS concentrations in serum and drinking water. Development of models for determining serum PFAS concentrations from measured PFAS concetrations in drinking water. May be used as screening tool without the need of HBM.	The primary objective was to characterize human exposure to PFAS in the areas of the Veneto region affected by water contamination. Secondary objectives were to identify any subgroups at incremental exposure/risk and to evaluate PFAS exposure as a function of place of residence, socio-demographic characteristics, lifestyle, drinking-water consumption and diet, in order to give indication to citizen to reduce their exposure.	Primary question: **What is the main source of exposure that causes the PFAS contamination of Lebring-St. Margarethes drinking water?** Secondary question: Are the PFAS levels in drinking water a potenial health risk, and what needs to be done to minimize or better eliminate the PFAS drinking water contamination?	Primary question: **Do the members of the cow grazer association have elevated PFAS levels compared to the Danish normal range determination and a cross-sectional description of clinical results related to lifestyle characteristics from questionnaire**	**Question 1:** To what extent do the measured PFOA serum levels of the local residents (from the DuPont factory in Dordrecht) correspond to the calculated values calculated from the exposure model of the RIVM? **Question 2: Are the measured PFOA serum levels of these local residents higher than a control group that lives elsewhere and thus have not been exposed to PFOA through the air?**	PFAS-concentrations in blood plasma of residents exposed to PFOA-contaminated drinking water or in blood plasma of anglers consuming fish from contaminated water bodies
type of study	cross-sectional HBM study in hotspot; no reference group was included. Data from previous Flemish general population campaigns from not contaminated sites were used as reference	Prospective cohort, including background-exposed references from nearby municipality.	observationa l study	temporal trend study, follow-up study on children and mothers, exposure assessment, and water- to-serum levels modelling	exposure assessment and modelling	HBM study with a reference group. The subjects of the reference group were selected with the same characteristics (gender, age…) of the study (exposed) subjects, but residing in an area defined as "not contaminated" on the	Environmental Monitoring: measure PFAS in groundwater, wastewater effluents, groudwater close to waste disposal sites, drinking water and meat	Clinical examination and HBM (Human Bio Monitoring). No reference group was included. The normal range was determined on data from Danish biobanks of plasma samples from 323 subjects aged 30–70 years with known SARS-CoV-2 infection (https://doi.org/10.1371/journal.pone.0244815).	Cross-sectional HBM study in a hotspot, with a control group.	cross-sectional study, later cohort study

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						basis of the data available on PFAS contamination of the water supply system.				
(paired) monitoring of environmental exposure	not foreseen in this phase 1 study; existing data on PFAS in environment (previous study) are available; in a follow-up study (starting mid 2022) paired environmental data on PFAS (soil, dust, water, local foods) will be collected	Drinking water analyzed in 2013 for PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFBS, PFHxS, PFHpS and PFOS. Attempts have been made to measure PFAS in lake sediments.	Water samples were taken and analyzed several times from Mid Aug to 3 Sep. For human exposure, 26 workers provided the first round serum samples, then 17 workers with high serum levels provided four rounds paired serum and urine sample. In total, five rounds of serum sampling (started from September) and four rounds of urine sampling (from October), at one-month interval, were collected.	drinking water PFAS levels were assessed through the municipal drinking water work	Measurements of PFAS in drinking water and serum	Several PFAS concentrations in groundwater, surface water,and drinking water were available before the HBM study. After also food matrices have been analyzed.	Environmental samples have been monitored to identify the main sources of exposure	The grass and soil of the meadow (canal) and the surrounding area were monitored for PFAS. The drainage channel running though the meadow had concentrations up to 9000 ng/l water Soil test from a near ditch showed concentration up to 6.100 µg/kg soil. By removing sludge from the ditch, the concentration has been reduced to 2.700 µg/kg soil. Measurements of four grass samples of the meadow. The highest concentrations were found in the grass of wet areas of 165 ng/g. The other tests showed 15,8 ng/g, 13,3 ng/g and one test did not contain measurable amounts of PFOS. It is estimated the cattle most likely have been contaminated though both grass and water from the stream running though the meadow Monitoring of fish from Korsør Nor (saltwater lake) was performed. 6 tests of different fishes: Flounder, shrimp, eelpout, sticklebacks, and gobies. These tests have not shown levels of PFOS harmful to health/findings of concern. In the allotment garden association Rundingen in Korsør, several crops, fx Jerusalem artichokes, have been tested for PFAS and did not show any findings of concern.	Not foreseen in this study. No measurements were taken in the area of the factory.	PFAS-concentrations in drinking water and in fish

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biomarkers of exposure and selection criteria	13 PFAS compounds: C4: PFBA, PFBS; C5: PFPeA; C6: PFHxA, PFHxS*; C7: PFHpA, PFHpS; C8: PFOA* PFOS*; C9: PFNA; C10: PFDA; C11: PFUnA; C12: PFDoA selection criteria: these are the compounds covered in the HBM4EU accrediation for analyzing PFAS in serum *: both linear + linear + branched compounds have been analysed	Measured levels in maternal serum, cord serum and child serum: PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFPeS, PFHxS, PFHpS, L-PFOS, 3/4/5m-PFOS, 2/6m-PFOS. Measured levels in colostrum and mature milk; PFOA, PFNA, PFDA, PFUnDA, PFOS, PFHpS and PFHxS.	15 PFAS were measured in drinking water: PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA; PFUnDA, PFDoDA, PFBS, PFPeS, PFHxS, PFHpS, PFOS, and 6:2 FTS. 16 PFAS were measured in serum: PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFBS, PFPeS, PFHxS, PFHpS, L-PFOS and three branched PFOS (1m, 3/4/5m and 2/6m). 11 PFAS were measured in urine (same as serum except PFPeA, PFNA, PFDA, PFUnDA and PFDoDA)	PFAS levels in serum and drinking water		Serum samples were analyzed for nine perfluorocarboxylic acids (PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUdA, and PFDoA) and three perfluorosulfonates (PFBS, PFHxS, and PFOS). Selection criteria were compound prevalence in human matrices and their presence in contaminated water from the region.	PFAS compounds: 20 PFAS listed in the the EU drinking water directive (Directive (EU) 2020/2184) and others (4:2 FTSA, 6:2 FTSA, 8:2 FTSA, DONA, GenX and F53B)	5 PFAS compounds: PFOS, PFHxS, PFOA, PFNA, and PFDA were measured in the HBM.These were chosen based on the substances being present in the meat and small pilot study.	PFOA (C8)	PFOA, PFOS, PFHxS, PFHxA, PFPA, PFBA, PFNA

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biomarkers of effect and selection criteria	none; biomarkers of effect have not been measured; it was not in the scope of this study to find associations between exposure and effects; in a follow up study (starting 2022) biomarkers of effect will be measured	No biomarkers measured so far but all samples are biobanked. Initial analyses will focuson datafrom medical charts.	No	no		Biomarkers of effect have not been measured	none; biomarkers of effect have not been measured	Biochemical measurements of liver-enzymes, kidney function, long-term blood sugar, and cholesterol/lipid, thyroid hormones. These measurements were selected based on expert advice from studies of associations between PFAS and the health effects (Philippe Grandjean). Individual results have been communicated to the participants. The biomarkers of effect and the biomarkers of exposure as well as questionnaire data have not yet been compared, but it is under process.	None, biomarkers of effect have not been measured and no health questions were asked. It was not in the scope of this study to find associations between exposure and effects. At the same time of this study, a literature review on effects of PFOA on humans was done (see RIVM Report 2017-0086, 2017).	different follow-up studies: age of puberty, immune response to vaccination
information on determinants of exposure	All participants signed an informed consent and completed a questionnaire to provide informationabout socioeconomic factors, biological factors, home environment, residence time at the site, diet (with focus on consumption of local foods), life style factors, product use (focus on PFAS containing consumer products), potential professional exposure . Multiple regression models were used to study the effect of residence in Zwijndrecht (zone, orientation and time since living around the site) on biomarker levels, after correcting for other modifying factors	Primarily measured serum levels but lifestyle factors, including self-reported water consumption and residential history, are available from questionnaires.	Information on age, home address, employment history, working tasks, and sick leave and vacation days in August and September were collected by questionnaire. In addition, data on the number of glasses of water consumed per day, local fish consumption , and history of blood donation and medication were collected. For female	questionnaire info	questionnaire info	A questionnaire was administered to participants to obtain information on anthropometric and socio-demographic characteristics, lifestyle, drinking-water consumption, and diet. The main factors influencing PFAS serum levels were residence area and the related extent of drinking water contamination, well water consumption and consumption of own produced food. Gender, municipal water consumption, years of residence in the municipalities, and raising own livestock also played a role, while effects of other demographic and environmental factors were relatively weak.	Sampling sites have been chosen by experts after examination of the geographical characteristics of the area	The participants (members of the cow grazer association) were offered a blood test as part of the clinical examination by letter.While the blood samples were analyzed, the participant completed a questionnaire to provide information on socioeconomic factors, length of membership of the cow grazer association, possible exposures (this including consumption of meat, fish, vegetables, and berries cultivated in a radius of 2 km from the firefighting facility), general health and lifestyle factors, work, and health history. As well as information on blood donations, blood transplantations and pregnancies. The participants agreed by written informed consent to data processing. A biobank is also under establishment.	Participants filled in an online questionnaire about some personal data (gender, age, height, weight), length of residence, working time, working environment, smoking behavior and the position of the house in relation to the factory. These criteria were used for recruitment and a comparison of demographics between the study groups. Distance to the DuPont/Chemours factory and time living in the study area were used as determinants of exposure.	questionnaire on drinking water consumption, residence, potential professional exposure, consumption of locally grown foods

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			employees, questions about menstruation, pregnancy, and duration of breast-feeding were asked.							
selection of the study population	800 inviduals (> 12 year), aiming at a sufficient range in distance/orientation of home residence to 3M, and aiming at a sufficient strech in age categories because of the persistent character of PFAS children < 12 years were excluded because of sampling technique (blood) pregnant and breastfeeding women were given priority (i.e. the selection criteria in terms of distance/orientation of home residence to 3M and age categories did not apply to them	All pregnant women between 2015 and 2020. Background-exposed mothers from nearby municipality towards the end of the inclusion period. Final cohort size is 263 mother-child pairs.	All 26 workers were invited for first round serum sampling. Then 17 out of 21 workers with elevated PFBS were participated for a four-months follow-up	Ongoing HBM-study	Study participants drinking contaminanted water with a wide range of PFAS concentrations Recruitment of volunteer study participants	The study involved 629 subjects (507 from general population and a subgroup of 122 farmers residing in contaminated areas) residing in selected areas of the Veneto Region, affected and not affected by PFAS water contamination. Among the 507 subjects from general population, 257 resided in municipalities in the areas under impact, and 250 in municipalities in areas at presumed background exposure. In each area participants were selected and stratified by gender and age (age classes: 20–29, 30–39, and 40–51 years). Each subject had resided in an area for at least 10 years.	study population that is supplied by the contaminated drinking water (people living in the region)	All members of the cow grazer association (approx. 200) were offered analysis of blood samples. 187 blood samples were collected The 187 samples were of:183 members of the cow grazer association ; 2 fishermen – who for years had fished in Korsør Nor and had a massive intake of fish from Korsør Nor ; 2 Firefighters - Working as trainers at the firefighting training facility.The two fishermen and the two firefighters were included, when they sought medical attention at the department of occupational and social medicine with concerns of contamination.	382 local residents (> 18year) from Dordrecht, Sliedrecht and Papendrecht (response 58%). Participants with blood clotting problems or who were employee of DuPont were excluded. Based on emissions, living distance and living time in the area, four groups of local residents were defined from which residents were selected for the blood test: 1) long-term (who lived there until 1-1-2003, bcs decreased emmisions after this date) residents living in the close area around (+/- 750 meters) the factory (N = 41). 2) long-term residents living in a wider area around (+/- 1,5 kms) the facotry (N = 186). 3) short-term (after 1-1-2003) residents living in the (close or wider) area	170 children, 317 mothers, 204 men; 105 anglers

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									around the factory (N= 76). 4) a control group of people living in a residential neighborhood of Wittenstein (6.5 kms away from the DuPont/Chemours factory) where PFOA exposure via DuPont is not expected (N = 56) 5) residents who have lived in the close area around the factory, but have moved. This group has not been included in the statistical analyses (N=23).	
selection of the study area	combination of dispersion modelling and monitoring data: elevated levels of PFAS in the environment (soil, eggs and wildlife) detected up to 5-10 km distance from production site. This distance serves as a rough delineation of the affected area. This first phase PFAS blood sampling campaign was limited to inhabitations living the to 3 km radius from the 3M site because the highest contamination in the environment was found within 3km radius	Enrollment into Maternal Health Care in Ronneby, later also in Karlshamn (reference).	Arvidsjaur airport, the hotspot with elevated PFAS in drinking water	Ongoing HBM-study in Uppsala	From information about PFAS contamination of drinking water in the area around the airports	Study areas were selected by local authorities on the basis of the data available on PFAS contamination of the water supply system. Subjects were recruited in areas with evidence of drinking water contamination, and in neighboring areas of the Veneto Region unaffected by water contamination (reference group).	The study area has been selected since previous monitoring data showed that the drinking water in this region is contaminated with PFAS		No data available on how the close and wider area were defined.	areas supplied with contaminated drinking water, reference area; Anglers: holders of a fishing license in the contaminated water body (Lake Moehne) with different consumption habits of locally caught fish (5 categories: no consumption up to more than 3 times/month)

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participation rate	about 8 % of the population meeting the selection criteria was candidate to participate. About 50 persons were not included because this number exceeded the foreseen number of participants	13 %. 228 mothers from Ronneby, approximately 300 women give birth in the municipality per year.	100% for first sampling, 81% for follow-up.	About 45% of the first-time mothers that are contacted are participating in the POPUP-study	varying			Not known but close to all. Extra 36 persons were later enrolled with results pending	382 local residents of the DuPont/Chemours factory participated in the study = participation rate of 58%.	different studies: 68 - 80 percent (Arnsberg), Anglers 14 %
exposure assessment	Main results: PFOS (l + b): P5: 4,13 ng/ml GM: 22 ng/ml; P90: 84 ng/ml; P95: 145 ng/ml; highly elevated compared to Flemish reference group PFOA (l+b): P5: 0,45 ng/ml; GM: 1,39 ng/ml; P90: 2,95 ng/ml; P95: 3,63 ng/ml; similar compared to Flemish reference group PFHxS: (l+b): P5:0,34 ng/ml GM:1,53 ng/ml; P90: 4,75 ng/ml; P95: 7,73 ng/ml; slightly elevated compared to Flemish reference group other PFAS compounds: more or less comparable to Flemish reference group	Serum measurements in mid pregnancy in ng/ml (median, Q1, Q3): Total PFOS 16 (4, 44); PFHxS 9 (1, 35); PFOA 1.8 (1.0, 3.4); PFNS 0.4 (0.3, 0.6).	PFHxS showed the highest serum concentration in the airport employees, with a median level of about 102–225 times higher than the level observed in the reference population. In addition, the median PFPeS concentration, although lower than PFHxS, was about 175–380 times higher than the maximum level in the reference population. Urinary PFAS levels were very low compared with serum. PFBS showed the shortest	Different areas of Uppsala recieved different amount of the contaminated drinking water. After 2012 when the contamiantion was discovered the levels were reduced. Median levels (max levels) in water in the contaminated wells were in samples from 2012-2013: PFHxS 83 ng/L (130), PFOS 47 ng/L (65), PFBS 13 ng/L (26), PFHxA 13 ng/L (21), PFOA 11 ng/L (17).	Serum and drinking water PFAS concetrations	Contaminant concentrations were significantly higher in exposed (E) subjects than in not exposed (NE) subjects for nine of the analysed substances (PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFDoA, PFBS, PFHxS, and PFOS). The largest difference was observed for PFOA: median value of the E group (14 ng/g) was eight times higher than the median value of the NE group (1.6 ng/g). Subjects residing in the local sanitary unit 5 (U5), were contamination had affected both municipal and well water, had the highest levels of PFOA among general population, with a median value (74 ng/g) 45 times higher than that estimated for the NE group. Exposed farmers (EF) showed the highest PFOA median concentration (40 ng/g all the group and 160 ng/g EF from U5).	No data on PFAS levels in serum The sum of 20 PFAS in the water samples was above 0.1 µg/L: in the fire pond of the fire academy, groundwater within the "safety area" of the waste disposal site "Rösselgrube", in the wells of several waterworks as well as drinking water for farm animals. Maximum level in the fire pond samples was 0.145 µg/L for the sum of 20 PFAS; the sum of 20 PFAS was onyl above 0.1 µg/l within the "safety area" of the waste disposal site with a maximum level of 0.189 µg/L; substitutes for legacy PFAS such as DONA, GenX and F53B as well as fluorotelomersulfonic acids (4:2 FTSA, 6:2 FTSA and 8:2 FTSA) were not detected. Four drinking water samples showed levels above 0.1 mg/L for the sum of 20 PFAS (range 0.152 - 0.697 µg/L); highest concentrations in the	Main results of PFAS in serum for the 187 participants: PFOS: GM: 43 ng/ml, range: 1.1-553 ng/ml PFHxS: GM: 3,1 ng/ml, range: 0,01-38 ng/ml PFOA: GM: 1,0 ng/ml, range: 0,1-4,9 ng/ml PFNA: GM: 0,5 ng/ml, range: 0-2,4 ng/ml PFDA: GM: 0,2 ng/ml, range: 0-1,2 ng/ml 63% of the participants had elevated PFOS levels compared to the estimated danish normal range determination on 21,2 ng/ml 64% of the participants had elevated PFHxS levels compared to the estimated Danish normal range determination on 1,9 ng/ml The other PFAS compound levels were mainly comparable to the estimated Danish normal range determinations. Please notice: Normal range determination is defined as 97,5 % of the study population is beneath this concentration. This is not necessarily a healthy concentration. The normal range is used for blood sample results in clinical work and is used here as the interest lies in if the participants have higher levels than the rest of the danish population. The median/mean is not of interest	* PFOA results for group 1: min: 1,3 ng/ml; P25: 5,5 ng/ml; P50: 10,2 ng/ml; P75: 26,7 ng/ml; max: 147,4 ng/ml; GM: 11,3 ng/ml * PFOA results for group 2: min: 0,3 ng/ml; P25: 2,1 ng/ml; P50: 3,4 ng/ml; P75: 5,4 ng/ml; max: 24,1 ng/ml; GM: 3,4 ng/ml * PFOA results for group 3: min: 0,1 ng/ml; P25: 1,4 ng/ml; P50: 2.8 ng/ml; P75: 4,7 ng/ml; max: 45,7 ng/ml; GM: 2,7 ng/ml * PFOA results for group 4: min: 0.9 ng/ml; P25: 2,6 ng/ml; P50: 3.4 ng/ml; P75: 4,8 ng/ml; max: 14,1 ng/ml; GM: 3,6 ng/ml * PFOA results for group 5: min: 0.5 ng/ml; P25: 3,3 ng/ml; P50: 6,0 ng/ml; P75: 9,7 ng/ml; max: 14,1 ng/ml; GM: 5,2 ng/ml	1. Arnsberg 2006: PFOA levels in blood plasma of residents living in Arnsberg were 4.5–8.3 times higher than those for the reference population (arithmetic means Arnsberg/controls: children 24.6/5.2 µg/L, mothers 26.7/3.2 µg/L, men 28.5/6.4 µg/L). Consumption of tap water at home was a significant predictor of PFOA blood concentrations in Arnsberg. 2. Anglers 2008: PFOS concentrations in blood plasma ranged from 1.1 to 650 µg/L (PFOA: 2.1-170 µgg/L; PFHxS: 0.4-17 µg/L; LOD: 0.1 µg/L). A distinct dose-dependent relationship between fish consumption and internal exposure to PFOS was observed.

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			half-life {average 44 d [95% confidence interval (CI): 37, 55 d]}, followed by PFHpA [62 d (95% CI: 51, 80 d)]. PFPeS and PFHpS showed average half-lives as 0.63 and 1.46 y, respectively. Branched PFOS isomers had average half-lives ranging from 1.05 to 1.26 y for different isomers. PFOA, PFHxS, and linear PFOS isomers showed average half-lives of 1.77, 2.87, and 2.93 y, respectively.				drinking water samples were detected for PFOS, 6:2 FTSA, PFHxS and PFPeA; if besides the sum of 20 other PFAS were included as well, the sum of all detected PFAS ranged from 0.153 - 0.837 µg/L. Out of 22 PFAS, PFBA, PFHxA, PFHpA, PFOA, PFBS, PFHxS and PFOS were detected in all drinking water samples. PFPeS, PFHpS, 4:2 FTSA and PFNA were detected in a few samples. The sum of 20 PFAS exceeded the level of 0.1 µg/L in drinking water for farm animals (0.148 µg/L); highest concentrations were detectd for PFPeA, PFHxS, PFOS and 6:2 FTSA. Four pork meat samples and one cow meat sample were analysed: PFAS were detected in all meat samples, mostly PFOA and PFOS. The sum of all PFAS in cow meat was ≤1.9 ng/g. Maximum concentration of the sum of all PFAS was 5 ng/g (3.8 ng/g PFOA, followed by PFHxA, PFHpA, PFHxS and PFOS) in pork meat. These concentration would exceed the	in the clinical work, but is relevant in research.	**Question 1**: the median values of group 1 and group 2 are (slightly) lower than the calculated values of the model of respectively 13.5 and 8.5 ng/ml => the measured and predicted values correspond well. The model calculations are a good method to derive real serum PFOA levels in the population. So it is likely that the residents of the area around DuPont/Chemours (group 1 and, to a lesser extent, group 2) have been exposed to high concentrations of PFOA for a long time in the past. **Question 2**: PFOA in serum group 1 > 2, 3, 4 ; PFOA in serum group 2 > 3. Group 2 and 3 show serum PFOA values corresponding to background values such as those found in European studies (3.5 ng/ml). Some of the residents (4.7%) have higher blood values than the average maximum background exposure levels from various European studies (21 ng/ml).	

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Uppsala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
							upcoming proposal for treshold levels in meat.			
health assessment	- (not investigated as such) using the HBM-I and -II values for PFOS and PFOA (German HBM commission) and EFSA TWI, a health risk was identified since 60 % of the participants exceeded HBM-II for PFOS	Medical charts from routine visits.	No	No. Birth weight has been evaluated but not linked to drinking water exposure. Serum samples are biobanked.	Risk assessment have been performed by the Swedish Food Agency/regional clinics of environmental and occupational health. Risk communication by regional clinics. No health assessment.	Health assessment was not investigated in the HBM study; in the light of the results of the study, the Regional authorities defined a regional health surveillance plan including HBM and health assessment. Using the HBM-I and -II values of the German Human Biomonitoring Commission for PFOS and PFOA: 64% E subjects had PFOA serum concentrations higher than the pertinent HBM II value (26% exceeded the HBM II values> 10-fold) and 20% E subjects had PFOS serum concentrations above the HBM II Value.	The PFAS uptake via drinking water from lower contaminated sites was calculated for children (range 0.11 - 0.33 ng/kg bw/d) and adolescents and adults (0.06 to 0.29 ng/kg bw/d). Compared to the suggested TWI of 4.4 ng/kg bw/w by the EFSA and considering the uptake of 2 L per day for adults and 1 L per day for children: the calculated uptake of the sum of four PFAAs in children ranges from 0.56 to 1.7 ng/kg bw/d, and in adults from 0.19 to 0.57 ng/kg bw/d. Compared to the suggested TWI of 4.4 ng/kg bw/w by the EFSA, children exceeded the TWI by up to 14.6 times, adolescents by up to 8.7 times and adults by up to 12.6 times. Compared to the suggested TWI of 4.4 ng/kg bw/w by the EFSA and considering the uptake of 2 L per day for adults and 1 L per day for children: the calculated uptake of the sum of four PFAAs in children	**under investigation**	Not investigated as such. At the same time of this study, a literature review on effects of PFOA on humans was done (see RIVM Report 2017-0086, 2017). There was no comparison with healthbased guidance values.	routine blood tests, pubertal development, response to vaccination

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Upssala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
							ranges from 10.18 to 47.19 ng/kg bw/d, and in adults from 3.43 to 15.73 ng/kg bw/d. Higher risk for adverse health effects can not be excluded for the population consuming drinking water from the higher contaminated sites.			
indentified determinants of exposure or health effects	in view of demographic factors, concerning PFOS in serum - elevated levels in older people (+15 %; per increase of 10 years) - lower levels in women versus men (-15%) - higher levels in individuals exposed to soil particles during work, hobby or education (+ 22%) - lower levels in people from non Belgian origin vs belgian origin (-46%- - lower levels in people with obesitas (-28 %) in view of relation to the environment, signifcant positive associations were found between (l+b) PFOS serum and - Distance & orientation in relation to 3M site (higher in 0-1.5 km versus 1,5-3	No	No	no	Determinants of exposure: drinking water consumption, serum PFAS concentrations. Background exposure from HBM of populations with drinking water PFAS concetrations below LOQ.	PFOA in serum: • higher levels in exposed versus not exposed • higher levels in exposed farmers versus general population • higher levels in men versus women • higher levels in subjects with higher BMI • higher levels in subjects residing in U5, were contamination had affected both municipal and well water • positive correlation with municipal water consumption • positive correlation with years of residence in the municipalities	- drinking water deriving from the contaminated wells - pork and cow meat	Determinants of exposure: Beef (Meat from veal) The evaluation on health effects is under process.	Distance to the DuPont/Chemours factory and time living in the study area: residents who have lived in the vicinity of the factory for a long period of time (group 1) have higher concentrations of PFOA in their blood than residents who live further away (group 2) or who have lived in the vicinity for shorter periods of time (group 3). No associations with other determinants were investigated.	Arnsberg 2006: consumption of drinking water, age, locally grown fruits and vegetables and male sex were associated with increased PFOA-concentrations, BMI was inversely associated (DOI: 10.1289/ehp.11064). Anglers 2008: consumption of locally caught fish and age were associated with increased PFOS-concentration in blood plasma (DOI: 10.1021/es104391z)

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Uppsala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
	km zone; higher in SW orientation) - time since living in the study area - consumption of local eggs **(strongest factor among all exposure determinants!)** - use of groundwater **after correction of other confounding factors** assocations for PFOA, PFHxS and PFNA: see report. Focus in this overview is on PFOS because of dominance on PFOS in exposure profiles									
identified vulnerable populations	low SES status was not identiefd as exposure determinant; remark the the recruited population was not representative for the region	No	No	no	no	People using well water, growing and consuming own vegetables and raising own livestock were more subjected to PFAS contamination exposure	pregnant and breastfeeding women, newborns, children, adolescents, women of childbearing age, and adults that have consumed drinking water deriving from the higher contaminated wells	Pregnant and lactating members, as well as children, of the cow grazer association.	No vulnerable populations were identified.	

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Upssala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
commmun cation of the results: which audiences targeted	Flemish authorities implemented a communication strategy to inform **citizens** about the study results. All participants first received the collective results of the study as well as their personal results. The particpants were invitated to a information session organized in Zwijndrecht informing about the collective results. This information day included a plenary session and a 'info-market' where participants had the opportunity to talk with the researh team. Afterwards, all participants were given the opportunity to consult a physician, to discuss their personal results. The policitans, the press and the general public wer informed in the same week; communication with the policitians, general public and press was after the participants had received their result (this is the basic principle in HBM communication in Flanders)	Levels in serum and milk reportedback to participants as medians in Ronneby and Karlshamn in each sample type and the individual's levels.	The individual serum PFAS level were reported to each individual with a comparison to the population level (e.g. higher or lower than the average level)	Results on elevated serum levels in mothers and children that have lived in areas receiving contaminated drinking water have been published.	Communication through the health clinics, mass media, Swedish Food Agency´s home page. Public reports from the regional environmetal and occupational health clinics and the Swedish Food Agency.	At the beginning of the PFAS contamination discovery, a series of communications on the PFAS contamination of ground, surface and drinking-water took place between the Regional Prevention Directorate and the Ministry of Health, communications on the same subject were taking place between local and national environmental authorities. A communication plan was also organized beginning in 2013, it initiates involving mayors of the affected municipalities and directors of the health care trusts. General population was informed by health care trusts and by the web site of the Veneto Region. Press conferences were organized to inform the press and the general public. Scientific publications were produced reporting results of the HBM study and other studies conducted in the field.	Contaminated drinking water wells were closed. Further communcation strategies for different audiences are going to be developed.	The Department of Occupational, Environmental and Social Medicine, who performed blood sampling and had the main contact to the participants prioritized to inform all the participants with elevated PFAS by phone and email on their personal results prior to any press release. The results were sent by letter to the participants with descriptions of how to interpret the results. Moreover, they were offered an individual health consultation at the clinic. The participants were also offered counseling with environmental medical psychological expertise. The department frequently sends out information letters to the cow grazer assertion, to keep them updated on the situation. An open counseling phone-line was established ensuring that the participants could call if they had questions The participants, members of the cow crazing association were invited to two informative meetings (in May and August 2021) about the results and plans for further investigation. General practitioners in Korsør were informed on how to handle worried residents. The press and the public were informed by the Department of Occupational, Environmental and Social medicine, and scientist in Denmark were interviewed by the press about the health risks, the procedure, and the severity of the situation	Participants who wanted to know their PFOA levels were informed about their individual PFOA blood value.	Participants were informed in writing; Information sessions were organized (ministry, science, local authorities), intensive press coverage.

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Upssala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
short term impacts (policy making)	-immediately following the communication of the study results, the minister promised to offer the opportunity to all residnets livng in the 5 km zone around 3M to analyse PFAS in their blood (70.000 people) - extending the perimeter applicable to 'no regret measures' (advices to citizens to lower their exposure by avoiding/reducing consumption of local eggs and vegetables and ground water - a few days following the communication of the study result, the Flemish authorites (environmental inspection) forced 3M to stop (temorpraly) all production processes emitting PFAS substances. - investigation/screening of other potential PFAS hotspots in Flanders	The contaminated waterworks was immediately closed in 2103 when the contamination was discovered. Uncontaminated water now supplied to the whole municipality from another waterworks. We aim to provide data for evidence-based rbreastfeeding recommendations for highly exposed mothers and identify sensitive outcomes in their children for which intensified monitoring through Child Health Care Services might be relevant.	Once high PFAS level in drinking water was discovered, warnings to not drink or cook with tap water were immediately issued and clean water from tanks was immediately supplied.		Development of action limits for PFAS in drinking water by the Swedish Food Agency.	Associations of citizens have been founded to request political measures to manage PFAS contamination. 'The communication of the PFAS serum levels received a huge amount of attention in journals, TV and web sites. A UN human rights expert recently visited the contaminated sites in the Veneto region.	Contaminated drinking water wells were closed. Set measures to identify the main sources of exposure, prevent further contaminations and take remediation measures if necessary. Communicate the issue with relevant stakeholders and involved population groups, plan further monitoring programs and its funding. Experts from the EAA and AGES suggest to investigate further the sources of exposure. First, continue with the drinking water monitoring to clarify the exposure situation. Secondly, main identified potential sources of exposure including six wastewater treatment plants, one industrial facility and five waste disposal sites are suggested for further investigations.	Requirement for water suppliers to screen for PFAS. - Mapping on potentially contaminated areas in Denmark including all firefighting facilities in Denmark. All potential contaminated areas were tested for PFAS contamination.	RIVM advised the following: * The Health & Youth Service, in consultation with the RIVM, should spread the findings of the study to general practitioners, midwives and medical specialists in the region.	waterworks installed activated charcoal filtering, HBM-studies, extensive PFAS-monitoring in drinking water and in soli contaminated by "soil conditioner"

	Belgium/ Zwijndrecht	Sweden/ Ronneby (Mother-Child Cohort)	Sweden/Arvidsjaur	Sweden/Upssala	4 PFAS hotspots in Sweden (Arvidsjaur, Luleå, Uppsala, Visby)	Italy/Some municipalities in the southwest of the Veneto Region	Austria (Lebring-St. Margarethes)	**Denmark/ Korsør - Slagelse municipality, Region Zealand**	Netherlands/ Dordrecht	Arnsberg, Germany
short term impacts (societal)	More than 100 individuals asked for a personal consult with the study physician, because they needed more information. Also scientists and policy makers received a lot of questions during the communication events. Citizen groups (grondrecht) build up a court case (legal claims against 3M); PFAS serum levels are element of this dossier the communication of the PFAS serum levels received a huge amount of attention in the press (e.g. first headline of the journals and news bulletin at national TV)	Information on individual serum levels in different sample types. Results will be communicated back to the society through public meetings and through the PFAS-Ronneby blog.	Our research group was contacted by the Arvidsjaur municipality immediately after the exposure was discovered. Biomonitoring of all employees at the airport was initiated 11 d after PFAS-free drinking water was supplied to the airport.		High costs for local authorities for remediation/distribution of clean water.	'A health surveillance plan was defined by the Veneto Region. The health surveillance plan included PFAS serum screening of the entire exposed population; subjects with higher PFAS values identified through the plan, were also invited to follow a diagnostic and possibly therapeutic path in internal medicine and cardiology clinics. The chemical plant producing PFAS was closed in 2018 and the company executives have been tried for environmental crimes.	Communicate the issue with involved population groups, provide clean drinking water (substitutes of current supply) till monitoring data show a clear PFAS decrease and no health risks are expected.	The Danish Health Authority established an expert group to discuss the handling of contaminated patients and worried residents in Denmark 'Focus on potential contamination in the rest of the country. - Political attention at all levels from minister to local community - The cow grazer association set up a work group to build up a compensation case.	RIVM expects that an (individual) health study among local residents will produce little to no health benefits for the people in question. In some cases the undesirable changes in the body which may occur as a consequence of exposure to PFOA can already be detected by standard controls and can therefore be treated. The possible serious health effects (such as kidney cancer, testicular cancer and ulcerative colitis) occur only on a very limited scale. As a result, the chance is small that a screening for these conditions will lead to the detection of any new cases. A number of the possible undesirable changes cause health effects that will be discussed in good time with GPs. People who are concerned about their health are advised to contact their GP. RIVM advised the following: * additional exposure study among participants with high PFOA	installation of charcoal-filtering in waterworks, fish consumption recommendations had been published by the Ministry for environment, HBM-studies

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									blood concentrations. * keep up with developments in the scientific literature on the effects of PFOA and international developments around health-based limit values.	
impact - research agenda	Additional research projects including a paired HBM and environmental monitoring of PFAS (environmental monitoring including locally grown food, soil, dust, air, water) was set up. besides the extension towards paired environmental monitoring, also biomakers of effect will be investigated. sources of environmental pollution and exposure routes) additional research on the current cohort: study was launched to couple HBM data into electronic medical dossiers, and assess the feasiblity to use this information for deriving exposure response functions	So far, we have confirmed that the transplecental and lactational transfer efficiencies are of similar magnitude in highly exposed mothers as in those with background exposure.	Study was performed in the workers to investigate the PFAS half-lives, especially for the short chain PFAS. One paper is published in EHP: https://ehp.niehs.nih.gov/doi/full/10.1289/EHP6785	Ongoing HBM-study. Elaboration of models for assessing PFAS exposure on population level (background + drinking water) based on results from this, and other hotspot areas in Sweden (manuscript in preparation)	Many PFAS studies ongoing in Sweden, funded by different reseach foundations/authorities	Additional research projects are on going or planned for the future.	Experts from the EAA and AGES suggest to investigate the sources of exposure. First, the five wells that are used for drinking water purposes in the region need to be investigated separately. Secondly, main identified potential sources of exposure including six wastewater treatment plants, one industrial facility and five waste disposal sites are suggest for further investigations. Measures are necessary to protect the larger groundwater body from PFAS exposure and ensure sufficient drinking water quality for the community - suggestions: restructur the drinking water wells, installation of activated carbon filters, dilute the	A medical clinical trial with the purpose of promoting elimination of PFOS by the use of oral anion exchange in humans with increased level of PFOS in the blood. Cholestagel/Colestyramin is the planned medicine. The study will include 60 participants from the cow grazer association with elevated levels of PFAS. The study is a crossover design, with randomization to two groups. After initial blood sampling, one group (Group A) will receive the medication for 12 weeks immediately, while the other group (Group B) is control. After the 12 weeks period and blood sampling, Group B will receive medication, while Group A is control. PFAS levels will be tested at the beginning of the trial, after the first 12 weeks and after 24 weeks		Environmental monitoring, HBM-monitoring; support of the derivation of HBM-values

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							water by mixing it with uncontaminated drinking water, continue with monitoring the food that is produced in the region, find effective measures to eliminate the entrence of PFAS into the environment. Identify and prevent further PFAS emissions.			
long term impact (policy making)	due to the PFAS crisis in Zwijndrecht, a polictial research commission was launched by the parlement. The conclusions from this commission are expected in February 2022	Development of breastfeeding recommendations and potentially intensified monitoring by Child Health Care Services.	The study provided evidence showing that populations with high daily exposure to short-chain PFAS from highly contaminated drinking water will have clearly elevated serum levels of these PFAS above background as long as exposure continues. Therefore, high short-chain PFAS contamination of drinking water may be a serious environment	The drinking water producer in Uppsala has sued the Armed Forces responsible for using fire-fighting foam containing PFAS.	Maximum limits of PFAS in drinking water - EU	A research commission was set by the Italian Parliament to amend the relevant laws about PFAS (DDL 2392, 2021. Misure urgenti per la riduzione dell'inquinamento da sostanze poli e perfluoroalchiliche (PFAS) e per il miglioramento della qualità delle acque destinate al consumo umano)	Continous monitoring and measures to keep PFAS level below guidance values	The Danish Health Authority has issued national guidelines for general practitioner and the general population on how to act and relate to PFAS contamination. (https://www.sst.dk/da/Viden/Miljoe/Miljoe-og-sundhed/PFAS). Stricter water quality requirements. The drinking water criteria is now for the sum of 4 PFASs 0,002 µg/L		

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			al health problem that should be taken into account in future epidemiological studies and policy making.							
references	https://assets.vlaanderen.be/image/upload/v1652873412/Bevolkingsonderzoek_PFAS_Zwijndrecht_-_Wetenschapppelijk_rapport_-_update_240222_vzdk8c.pdf https://www.vlaanderen.be/pfas-vervuiling	(unpublished results for the other child study) reference to other Ronneby study (general population: https://pubmed.ncbi.nlm.nih.gov/33360412/	https://ehp.niehs.nih.gov/doi/full/10.1289/EHP6785	Gyllenhammar I, et al. 2015. Influence of contaminated drinking water on perfluoroalkyl acid levels in human serum – a case study from Uppsala, Sweden. Environmental Research 140: 673-683. Gyllenhammar I, et al. 2018. Perfluoroalkyl Acids (PFAAs) in Serum from 2-4-Month-Old Infants: Influence of Maternal Serum Concentration, Gestational Age, Breast-Feeding, and Contaminated Drinking Water. Environmental Science and Technology 19;52(12):7101-7110. Gyllenhammar I,		http://dx.doi.org/10.1016/j.envint.2017.10.026	https://wissenaktuell.ages.at/download/0/0/c8d74003a4c6b74e4f2a773470f3a9c2f23200a8/fileadmin/AGES2015/Wissen-Aktuell/Wissen_aktuell_2021/Endbericht_POPMON_II.pdf	www.slagelse.dk/PFOSkorsoer	(based on Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Betekenis resultaten bloedonderzoek PFOA omwonenden DuPont/Chemours, 2017. and Rijksinstituut voor Volksgezondheid en Milieu (RIVM), PFOA-metingen in bloed, 2017.)	DOI: 10.1289/ehp.11064 DOI: 10.1021/es104391z

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				et al. 2019. Perfluoroalkyl Acids (PFAAs) in Children's Serum and Contribution from PFAA-Contaminated Drinking Water. Environmental Science and Technology 1;53(19):11447-11457.						

Annex 2: presentations of the PFAS hotspots workshop (2 May 2022)

HBM4EU

science and policy
for a healthy future

PFAS EU hotspots workshop

2 May 2022

1

Content

slides 3 – 17: introduction to HBM4EU – science to policy

G. Schoeters (VITO and University of Antwerp)

slides 18 – 45: human biomonitoring in PFAS hotspots in Europe: overview and experiences

K. De Brouwere (VITO)

slides 46 – 61: PFAS hotspots: policy implications

M. Uhl (EAA)

2

Short introduction to HBM4EU – science to policy

HBM4EU

science and policy
for a healthy future

PFAS workshop

2 May

Greet Schoeters, VITO & University of Antwerp

3

The European Human Biomonitoring Initiative - HBM4EU

5,5 years (2017-2022)

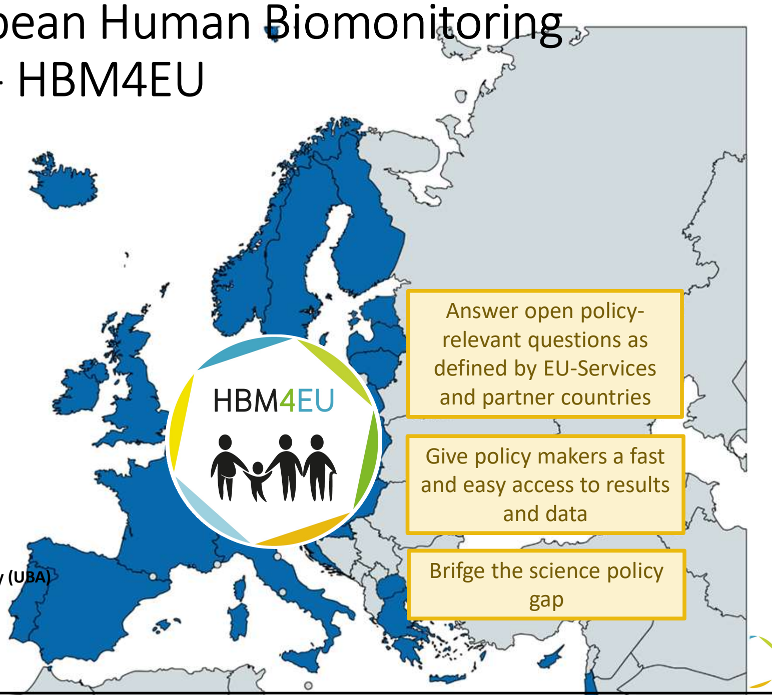
European Joint Programme
under Horizon 2020
Total budget: **~ 74 million €**

30 countries and the **European Environment Agency**

120 Partner organisations

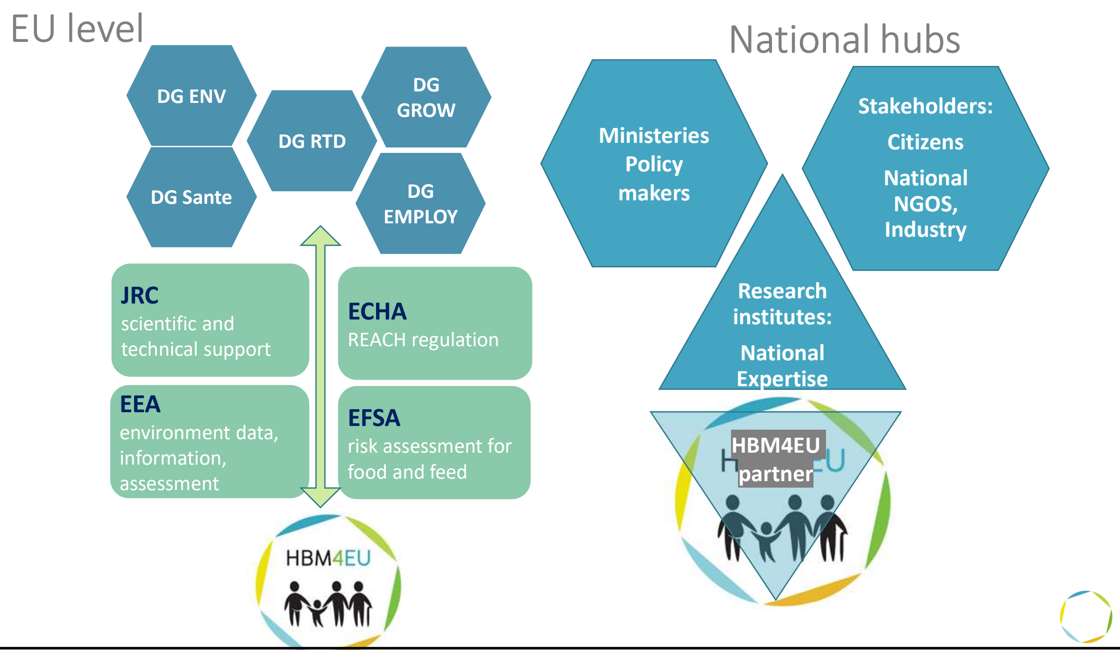
Coordinated by the
German Environment Agency (UBA)

Umwelt Bundesamt



4

Building a unique science policy interface to capture different perspectives



5

From Policy to science: prioritisation and capturing policy questions

Phthalates/DINCH Bisphenols Per-/Polyfluorinated compounds Flame Retardants Cadmium & Chromium PAHs and air pollutants Anilin family: MOCA Chemical mixtures Emerging chemicals	Acrylamide Aprotic solvents Arsenic Diisocyanites Lead Mercury Mycotoxines Pesticides UV filters

- What is the current exposure of the EU population?
- Are exposures different between countries? Why?
- Can we detect a significant decrease in levels after REACH?
- Are exposure levels above any health relevant health assessment values?
- Should the substance be subject to (further) regulation ?

6

From Science to policy

1. Health Based Guidance Values for 27 exposure biomarkers
2. Use HBM data to improve risk assessment
3. HBM based indicators to follow spatial and time trends of human exposure
4. Participative and deliberative process to translate results in policy options

7

HBM Guidance Values(HBM-GV) for the general population and for workers

D 5.2, D 5.6, D 5.14, D 5.15
peer reviewed publications

- *DnBP*
- *DiBP*
- *BBzP*
- *DEHP*
- *DPHP*
- *DINCH*
- *BPA*
- *Cadmium*

D 5.9

- **NMP** (peer rev. publication)
- **NEP** (peer rev. publication)
- **DMF** (publication subm.)
- **DMAC**
- **BPS** (publication subm.)
- **BPF** (no value, but dossier)
- **PFHXs** (no value, but dossier)
- **Deoxynivalenol (DON)**

D 5.12

- **Deltamethrin** (publication in prep.)
- **Cyfluthrin** (publication in prep.)
- **Mercury***
- **Chromium VI** (HBM-ELCR, refers to excess life time cancer risk for workers)
- **Toluene diisocyanate (TDI)** (no value, but dossier)

D5.11

- **Acrylamide***
- **Benzophenone 3***
- **Lead***
- **3-PBA***
- **1-OH PYR****
- **Acrylamide ****

* Provisional HBM-GV
** Estimated cancer risk 10^{-5}

Apel et al, Int J Hyg Environ Health. 2020 doi: 10.1016/j.ijheh.2020.113622
Ougier et al, Environ Int. 2021. doi: 10.1016/j.envint.2021.106563
Lange et al, Int J Hyg Environ Health. 2021 doi: 10.1016/j.ijheh.2021.113722
Lamkarkach et al, . Environ Int. 2021 Feb;147:106337. doi: 10.1016/j.envint.2020.106337

8

European HBM Platform: comparable HBM data

Survey design — Umwelt Bundesamt

Targeted fieldwork surveys — Ovnair Sepai, Public Health England

Lab analysis and quality assurance — A. Castaño&M.Esteban, cnsa, Instituto de Salud Carlos III

Data management and analysis

G. Schoeters & E. Govarts

9

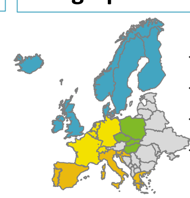
Background Sampling frame HBM4EU aligned studies

Inclusion criteria	Exclusion criteria
✓ General population	!no hotspot areas
✓ Samples collected between 2014-2019	! Specific targeted populations e.g. patient groups

Domains for which reliable data are needed:

Age
- ✓ Children (6-11y)
- ✓ Teenagers (12-19y)
- ✓ Adults (20-39y)

Geographical coverage



- ✓ North 21% → 2
- ✓ East 11% → 1
- ✓ South 28% → 3
- ✓ West 40% → 3/4

Sex
- ✓ Male
- ✓ Female

→ 50:50 ratio

Domains with minimal prevalence (10%):

SES socio-economic status
- ✓ Educational level (ISCED- classification from UNESCO)
- ✓ Level 0-6

Subject living environment

Inhabitants of
- ✓ Low
- ✓ Medium
- ✓ high density communities

Final HBM4EU Advisory Board meeting

10

Alignment of national studies PFAS

WP7 **Development of SOPs**
Questionnaires for PFAS
Communication materials
https://www.hbm4eu.eu/online-library/

WP9 **Network of qualified laboratories**

PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFBS, PFHxS, PFHpS, and PFOS

QA/QC assured HBM analysis (WP9)
21 qualified laboratories

WP8 **Alignment of studies in teenagers**

North	477 subjects
East	292 subjects
South	445 subjects
West	743 subjects

New analyses planned in aligned studies

Phthalates	DINCH	Perfluorinated compounds	Countries
✓	✓	✓	NO, SE, SK, SI, GR, ES, FR, BE, DE
✓	✓		PL
✓			CZ

North: 21%
East: 11%
South: 28%
West: 41%

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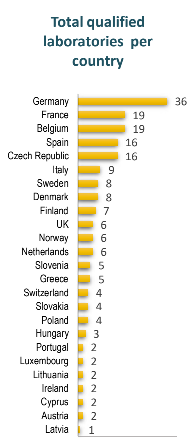
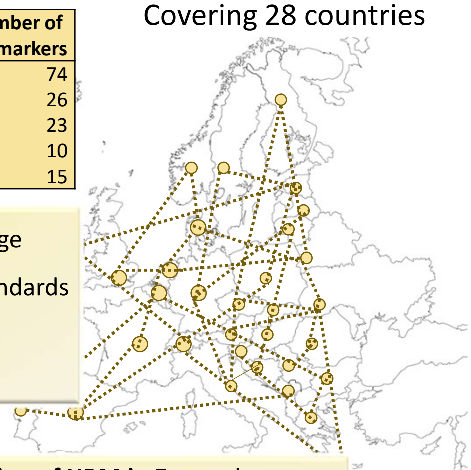
Sustainable network of laboratories



Number of qualified labs for	Number of biomarkers
At least 1 biomarker	74
<5 biomarkers	26
5-10 biomarkers	23
11-20 biomarkers	10
>20 biomarkers	15

- ✓ Knowledge Exchange
- ✓ Highest quality standards
- ✓ Collaboration
- ✓ Capacity Building

Covering 28 countries



Big step towards harmonisation of HBM in Europe!

12

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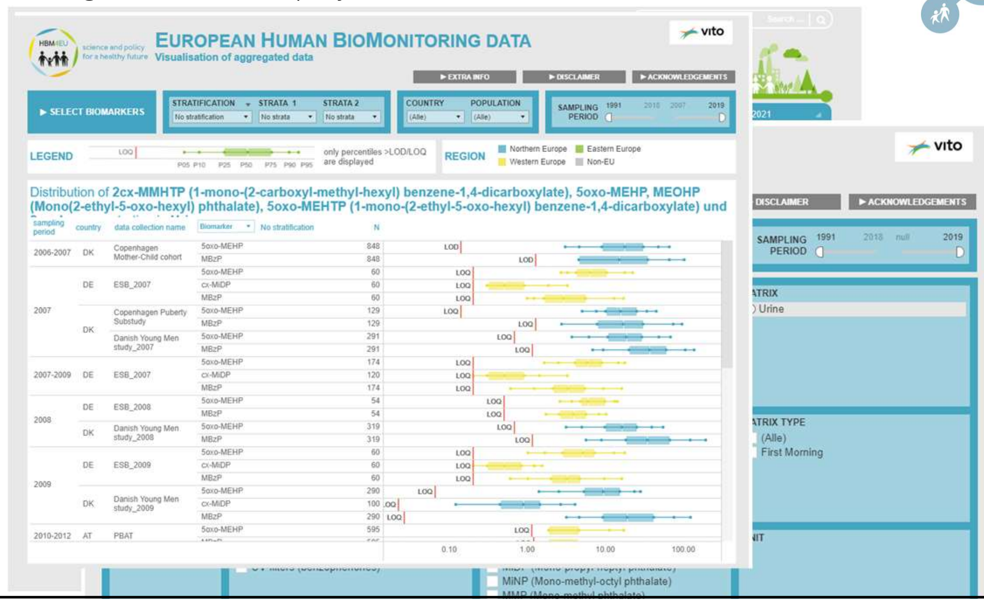
European Human Biomonitoring Dashboard

- Easy visualisation of summary statistics from existing HBM data collections from 1991-2019 through the HBM4EU project



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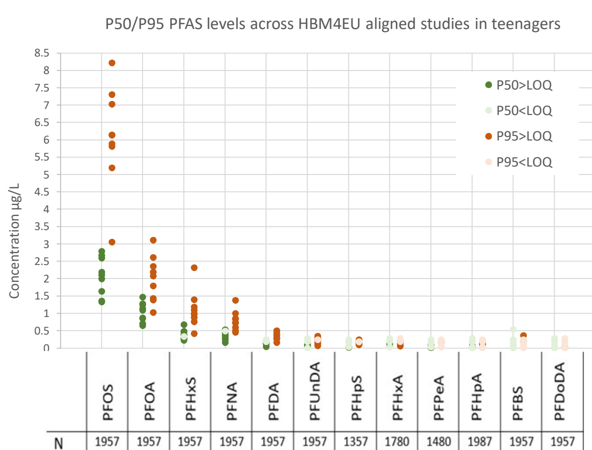
Exposure difference in regulated and alternative PFAS compounds in teenagers



Data is expressed in µg/L.
For values below LOQ the LOQ value is plotted on the graph.
Includes data from 7-9 EU countries: NO, SE, SK, ES, SI, EL, FR, DE and BE

- ✓ Alternative PFAS compounds have lower exposure levels compared to regulated PFAS compounds
- ✓ Large proportion of non-detects for alternative PFAS compounds,
  however big difference in absolute values of LOQs reached across studies
  → Lowering the LOQ is important for mixture risk assessment!

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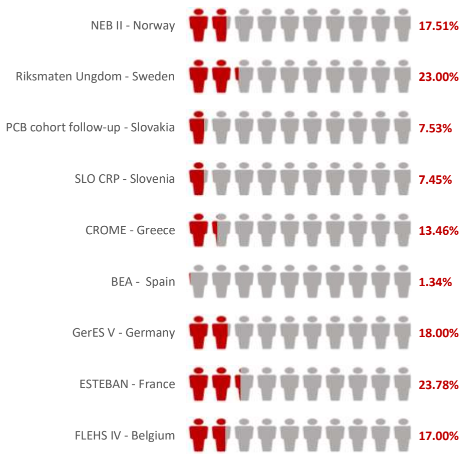
*Comparison with Health-Based Guidance values: EFSA opinion 2020 value**

**Derived for mothers -> approximation for teenagers*

Share of European teenagers with combined exposure levels to PFOA + PFNA + PFHxS + PFOS exceeding EFSA based value: 6.9 µg/L



Between 1-24% above EFSA opinion value for sum (PFOA, PFOS, PFNA, PFHxS) (6.9 µg/L*)

- ✓ Northern Europe: Norway = 18% & Sweden = 23%
- ✓ Western Europe: France = 24%, Germany = 18% & Belgium = 17%
- ✓ Eastern Europe: Slovakia = 8%
- ✓ Southern Europe: Spain = 1%, Slovenia = 7% & Greece = 13%

In 2020, the European Food Safety Authority (EFSA) set a new safety threshold for intake as sum of the four PFAS of 4.4 ng/kg body weight per week, which is corresponding to an internal blood level of 6.9 µg/L. These guidance values were based on serum levels in females aged 35 years old and effects on immunity of their newborns.

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Main messages — *European exposure data*

The HBM4EU aligned studies have generated baseline levels of internal PFAS exposure in serum/plasma of European teenagers, 12-18 years of age, for the period 2014-2021:

- ✓ There is a statistically significant **geographical difference** in exposure levels for **the legacy PFAS compounds (PFOS, PFOA, PFNA, PFHxS)**, with higher average concentrations in Northern and Western Europe.
- ✓ Risk of adverse health effects cannot be excluded. All studies have study participants that exceed the guidance values based on the **EFSA opinion 2020**, exceedances vary from **1-24%** with an overall exceedance of 14%.
- ✓ Detection frequency is strongly varying between studies for **alternative PFAS compounds**, however strongly dependent on the LOQs reached in the labs

  → lower LOQs crucial for mixture risk assessment

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Overall conclusion & policy messages

- ✓ **Regulation PFAS**: our results support the PFAS group restriction under REACH, as blood serum mixture data indicates that the HBM4EU population is at risk of developing detrimental effects upon exposure to PFAS.
- ✓ **Analytical methods:** it is crucial to lower LOQs to further improve future interpretation and risk assessment.
- ✓ **Exposure trends:** follow-up exposure levels is needed to closely monitor the effects of regulatory measures over time (PARC).
- ✓ European-wide analyses of **PFAS concentrations in relevant food items** are needed.
- ✓ **Origin of food** could be an important parameter determining PFAS exposure from diet.

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HBM4EU

science and policy for a healthy future

Human biomonitoring in PFAS hotspots in Europe: overview & experiences

Workshop, May 2

Katleen De Brouwere (VITO)

18

Introduction – background

Start of the PFAS crisis in Flanders

'no regret measures'

Communication of PFAS serum study 3M site

.... 1980 | 2002 | 2014 | 2019 | June 21 | Oct 21 | Jan 22... | 2023...

3M production site in Belgium (mainly PFOS)

3M stopped producing PFOS and PFOA in Belgium (continu other PFAS)

Scientific reports on PFOS in the environment & wildlife in at the site around 3M

PFAS serum In 800 residents around 3M site

Ad hoc interaction with other PFAS hotspots (Veneto, Ronneby, Germany)

EU PFAS hotspot network !!

HBM4EU activity under WP 5

19

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EU PFAS hotspot network !!

HBM4EU activity under WP 5

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Goal

PQ: PFAS exposure and health risks of inhabitants at contaminated sites in EU?

A. Set up a network of experts
B. Develop a guidance document on how to deal with Human Biomonitoring in (PFAS) hot spots

Guidance document that should be of practical use for new PFAS hotspot cases

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The PFAS hotspot network

VITO
Lead of HBM4EU PFAS hotspot activity

EAA, PIH, UCPH
HBM4EU partners of WP5 PFAS hotspot activity

All partners in the network

- Network HBM4EU and beyond
- Participants from Italy, Sweden, the Netherlands, Norway, UK, Denmark, Hungary, Germany, Austria, Iceland
- Contribution to discussion, exchange of information, PFAS HBM hotspot inventory and draft guidance
- 3 online meetings earlier this year

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Overview of investigated PFAS hotspots in EU

Major PFAS hotspots

HBM

- Italy: Veneto
- Sweden: Ronneby
- Netherlands: Dordrecht
- Belgium: Zwijndrecht
- Denmark: Korsør
- Germany: Altöttingen, Arnsberg, Rastatt-Bavaria

No HBM

- Austria: Salzburg Airport,...
- Norway: lake Tyrifjorden
- others

Numerous smaller PFAS hotspots

HBM: ??

Due to widespread uses of PFAS (e.g. firefight foam applications) many sites in EU appear to be PFAS contaminated (> 1000 ?)

Examples;

- Austria: inventory (suspected) hotpots
- DK: inventory of smaller hotpots
- Flanders: potential PFAS hotspots identified
- Etc.

Q: how to assess human exposure and health risks at these numerous sites…. ?

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Mapping information PFAS hotspots in Europe

STAGE	KEY CRITERIA
Pre-phase	Data available on environmental pollution and residents' health conditions
	Public concern
	Involvement of stakeholders and local actors
	Key decision to set-up HBM
	Funding
Study design and fieldwork	Type of study
	Biomarkers of exposure and selection criteria
	Biomarkers of effect and selection criteria
	Information on determinants of exposure
	Selection of the study population
	Selection of the study area
Results	Participation rate
	Exposure assessment
	Health assessment
	Identified determinants of exposure or health effects
	Identified vulnerable populations
	Communication of the results: which audiences targeted
Impact of the study	Short-term impact
	Long-term impact
	Levels: scientific, societal, policy making
	Involvement of stakeholders and local actors

Table 1. Four stages of a HBM study and key criteria.

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Source: *Colles et al. (2019); Epidemiol Prev Jul-Aug 2019;43(4):249-259. doi: 10.19191/EP19.4.A03.070 "Human biomonitoring as a tool for exposure assessment in industrially contaminated sites (ICSs). Lessons learned within the ICS and Health European Network"*

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PFAS hotspot in Veneto (Italy)

A chemical plant located in Trissino, near **Vicenza (Veneto),** started the production of PFAS in the late 6o'.

- For decades, the factory released wastewater into the ground, both surface water bodies and groundwater were contaminated.
- The problem was unveiled in March 2013
- Measurements of **drinking water samples** indicated that PFOA was the main contaminant
- Contamination reached public waterworks serving 20+ municipalities

Pitter et al. EHP 2020 Feb; 128(2):27007

source: C. Canova (1st network meeting)

25

PFAS hotspot in Veneto (Italy)

- Regional Health Surveillance: Monitoring of 12 PFAS compounds in serum
  - Population-based; free of charge screening program provided by the Regional Healthcare Service
  - Target population: residents in contamination plume (190km^2), cohorts of people born between 1951-2014 (n=105,000);
  - Recruitment started in 2017 (n recruited = 55,597)
- Exposure - health association research in this cohort:
  - Blood pressure, hypertension, lipid profile, metabolic syndrome, hormone levevels, Covid mortality

source: C. Canova (1st network meeting)

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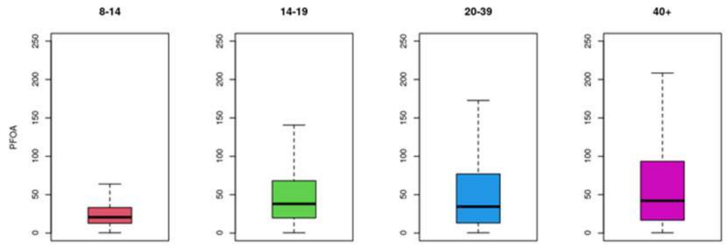
PFAS hotspot in Veneto (Italy)



ng/mL

Study	Population	PFOA (ng/mL)	PFOS (ng/mL)
Veneto Study 2019	Adults 20-39 - Exposed (Veneto)	35.8	3.7
Frisbee et al. 2009	Adults 20-39 - Exposed (Ohio, C8 project)	21.8	18.1
Ingelido et al. 2010	Adults 20-35 – Italian general population	2.87	4.46
Ingelido et al. 2018	Adults 20-51 – Not exposed (Veneto)	1.64	5.84

source: C. Canova (1st network meeting)

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PFAS hotspot in Ronneby (Sweden)

- Water quality montoring in Ronneby discovered very high PFAS levels in groundwater

PFAS (ng/L)	Contaminated waterworks	Uncontaminated waterworks	Reference
PFPeA	38	10	<0.6
PFHxA	320	3.6	<0.3
PFHpA	32	1.4	<0.3
PFOA	100	1.0	<0.3
PFNA	<1	<1	<0.6
PFDA	<1	<1	<0.6
PFUnDA	<10	<10	<2
PFDoDA	<10	<10	<2
PFBS	130	<2.6	<0.3
PFHxS	1700	4.6	<0.3
PFHpS	60	<1	<0.3
PFOS	8,000	27	<0.2
Sum PFAS	**10,380**	47.6	<5

- Contamination source: leakage of **firefigithing foam** used since 1985 at military airport
- Ronneby: population size: 28.000
- 1/3 of population connected to **contaminated water supply**

slide C. Nielsen (1st network meeting)

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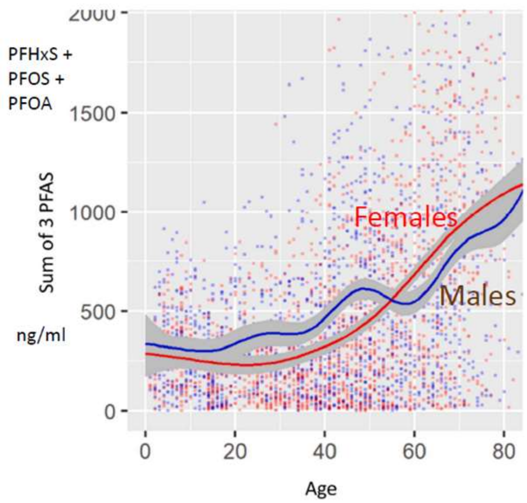
PFAS hotspot in Ronneby (Sweden)



Open blood samling in Ronneby, 2014-2015

	GM
Living in Ronneby 2005-2013 (or earlier) *N= 2219*	PFHxS: 210 ng/mL PFOS: 239 ng/mL PFOA: 13 ng/mL
Reference group (Karlsham) *N = 226*	PFHxS: 0.8 ng/mL PFOS: 4 ng/mL PFOA: 2 ng/mL

source: C. Nielsen (1st network meeting)

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PFAS hotspot in Ronneby (Sweden) : health research

Summary of published papers

No associations

- Inflammatory bowel diseases
- Thyroid diseases
- Endometriosis
- Breast cancer
- Prostate cancer
- Thyroid hormones
- Preeclampsia, gest hypertension
- Gestational diabetes

Associations

- Blood lipids/ cholesterol
- Polycystic ovarial syndrome
- (Uterine fibroids)
- Kidney cancer
- Testicular cancer
- (Thyroid cancer)
- miRNAs and DNA methylation

Source: C. Nielsen (1st network meeting)

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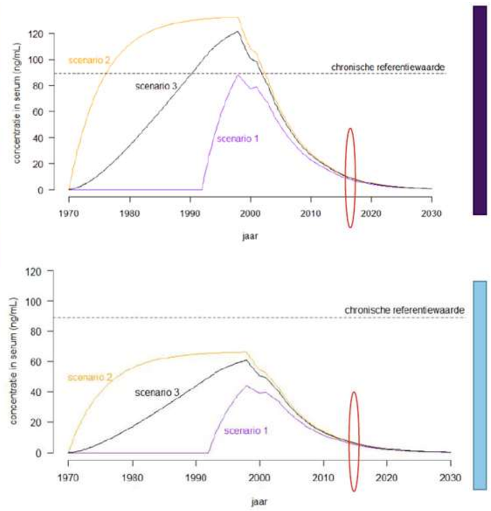
PFAS hotspot in Dordrecht (NL) : modelling & HBM

- PFAS polymer production site (Dupont/Chemours), emitting PFOA
- Retrospective modelling of serum levels via **inhalation** exposure (1998-2012)



n = 41
GM: 10.2 ng/mL
Modelled: 13.5 ng/mL

n = 186
GM: 3.4 ng/mL
Modelled: 8.5 ng/mL

Source: W. Bil (2nd network meeting)

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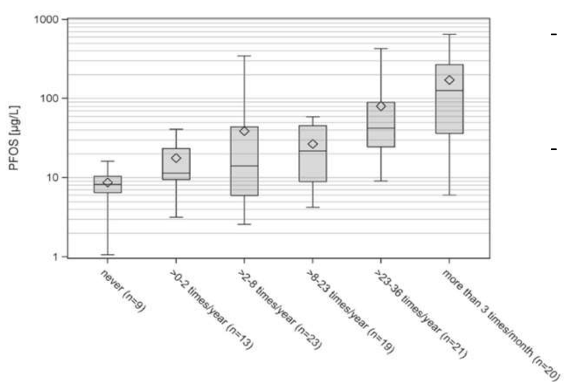
PFAS hotspot in (Germany)

- HBM in Arnsberg (2006): first German case
- contaminated by the **extensive application of soil conditioner/fertilizer** on agricultural areas. The fertilizer had been polluted with PFAS (presumably originating from disposal of industrial waste)



- Elevated PFOA in residents received contaminated drinking water
- High PFOS concentrations in anglers fishing in contaminated lake and rivers in the area

- Other German sites with HBM: Alttöttingen (2018) and Rastatt (2018)

Source: T. Göen (1st network meeting)

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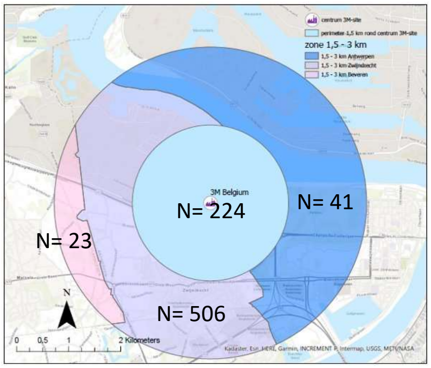
PFAS hotspot in Zwijndrecht (Belgium)



- PFAS production site (3M)
- 12.000 residents in 3km zone
- Elevated levels in environment & wildlife measured in the past
- 1st HBM in 796 people (2021)
- 2nd HBM (including paired environmental data): 2022-2023
- XXL HBM: 70 000 people invited

  (> 3km) to be started

Source: A. Colles (1st network meeting)

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PFAS hotspot in Zwijndrecht (Belgium)

PFOS (linear + branched)		
< HBM-I	> HBM-I - < HBM-II	> HBM-II
No health effects expected	*Adverse health effects cannot be excluded*	*Long-term adverse health effects possible*
9%	**32%**	**59%**

	GM	P95
	ng/mL	ng/mL
PFOS (l+b)	**22,4**	**84,0**
PFHxS	1,53	4,75
PFOA	1,39	2,95
PFNA	0,43	0,95

- Main environmental exposure determinants:
  - Distance and orientation of residence to 3M
  - Time living in < 3km from 3M
  - **Consumption of local eggs**
  - Use of groundwater

Source: A. Colles (1st network meeting)

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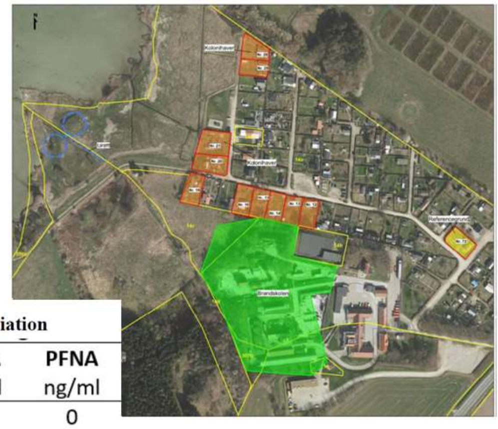
PFAS hotspot in Korsør (Denmark) ; 2020-2021

Source: **fire exstinguishing foam** used at military training center

Meadow & **cows** contaminated

Local food: 'Korsør Cow Grazing Association'

PFAS measured in serum of 187 members Korsør Cow Grazing Association



PFAS in members of Korsør Cow Grazing Association

187 pers.	PFOS ng/ml	PFHxS ng/ml	PFOA ng/ml	PFNA ng/ml
Min	1,1	0,01	0,1	0
Gennemsnit*	43	3,1	1,0	0,5
Max	553	38	4,9	2,4

* **Geometric mean**

Source: A. Lyngberg (1st network meeting)

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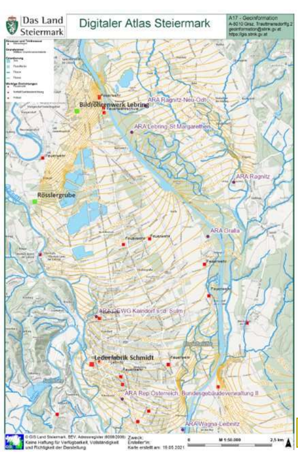
PFAS hotspots Austria

- POPMON I project – HCB contamination – dietary risk assessment confirmed by HBM
- POPMON II project – early warning of contaminated regions



one scenario: **PFAS** in the area of Lebring/ Leibnitz in Styria.

Potential sources

- Fire fighting training sites
- Contaminated sites
- Industry (Metallbau, Galvanik)
- Airport (Graz 30km)
- Wastewater treatment plants

Source: M. Uhl (2nd network meeting)

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PFAS hotspots Austria

- Analysis of drinking water wells, drinking water of animals and serum of pigs and cattle
- Estimated PFAS intake through locally produced food and drinking water exceeds the **tolerable weekly intake 3 to 4.5 times**
- Assumptions: only consumes local food and drinking water from this local
- **No human biomonitoring activities**
- Risk management
  - contaminated water wells closed
  - population informed

Source: M. Uhl (2nd network meeting)

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Overview of investigated PFAS hotspots in EU

Major PFAS hotspots

HBM:

- Italy: Veneto
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- Netherlands: Dordrecht
- Belgium: Zwijndecht
- Denmark: Korsør
- Germany: Altöttingen, Arnsberg, Rastatt-Bavaria

No HBM:

- Austria: Lebring/Leibnitz
- Norway: lake Tyrifjorden
- others

Numerous smaller PFAS hotspots

HBM: ??

Due to widespread uses of PFAS (e.g. firefight foam applications) many sites in EU appear to be PFAS contaminated (> 1000 ?)

Examples;

- Austria: inventory (suspected) hotpots
- DK: inventory of smaller hotpots
- Flanders: potential PFAS hotspots identified
- Etc.

Q: how to assess human exposure and health risks at these numerous sites.... ?

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Mapping of potential PFAS contaminated sites : example in Flanders

- 2016-2018 measurement campaign PFAS soil and groundwater at risk activities :
  - PFAS downstream use industries: paint, textile, paper, galvanic
  - Use of fire extinguishing foam
  - Landfill site
  - Water treatment plant
- In 2021: second call to local authorities
- Resulting in > 4000 locations (screening & prioritization is ongoing)

By far strongest contamination (training centers)

Source: G. Van Gestel (2nd network meeting)

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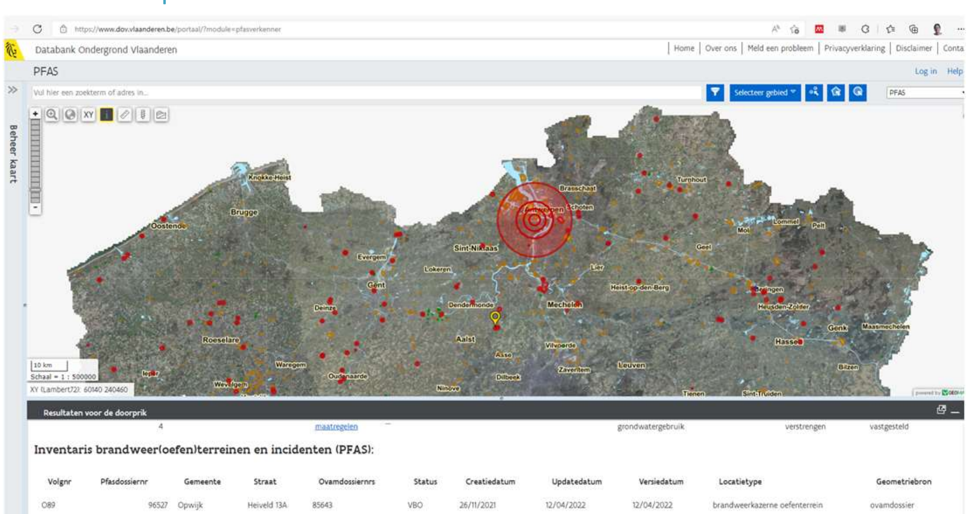
Mapping of potential PFAS contaminated sites example in Flanders



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Summary of exposure levels across hotspots

ng/mL PFOS

Altöttingen
Veneto
Zwijndrecht
C8*
Korsør
Ronneby

ng/mL PFOA

Zwijndrecht
Korsør
Dordrecht
Rastatt
Ronneby
Altöttingen
C8*
Veneto

*C8: US, Ohio (production plant)

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Summary

- PFAS hotspots **across all Europe** due to various types of contamination: production sites, firefighting training centers, soil amendments, etc.
- **Diverse exposure routes**: water, local food (fish, eggs, cows), air
- Diversity in dominant PFAS: mainly PFOA, PFOS – in relation to source
- 'relatively small' to extensive size of affected communities
- People at hotspots **exposed to up to > 100 fold general** 'background' population

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Summary

- **concern of PFAS exposure at hotspots has increased** a lot during the last couple of years;
  - Increasing number of studies (exposure data)
  - due to increasing evidence of adverse health effects due to PFAS (epidemiologic data)
  - decreasing health based reference values for external and internal exposure ; e.g. HBM-GV (EFSA, 2020)

→ Societal concern and policy impact !

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Concluding remarks

- A lot of attention for PFAS pollution for general population and hotspots
- PFAS research advanced a lot the last 5-10 years
- several research questions remain to investigate, and **hotspots are unique 'settings**' to do this
- Member of our network expressed the need for more collaboration in research projects across hotspots:
    - Broader exposure ranges
    - Higher study power
    - need for harmonized data
    - biobanking

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HBM4EU

science and policy for a healthy future

PFASs hotspots

Policy implications

Workshop, May 2

Maria Uhl (EAA)

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What are the political and social implications of PFAS contamination?

- What can we learn from the hotspot cases in European countries?
- What should be avoided, what can be recommended ?

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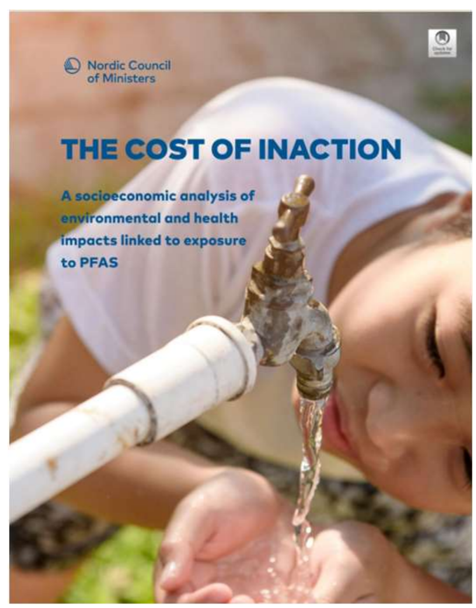
The cost of inaction

The **costs for remediating** some cases of contamination run to many millions of EUR. Total costs at the European level are expected to be in the **hundreds of millions of EUR as a minimum**.

Annual health-related costs were estimated to 2.8 – 4.6 billion EUR for the Nordic countries and **52 – 84 billion EUR for all EEA countries**.



https://norden.diva-portal.org/smash/get/diva2:1295959/FULLTEXT01.pdf

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Policy and societal impact PFAS crisis Zwijndrecht (Flanders)

Tijd voor antwoorden: waarom zweeg de politiek over PFAS-vervuiling?

8 december 2021 Tom Cochez

De top van chemiebedrijf 3M blijft elk verband tussen PFAS en risico's voor mens en milieu ontkennen. (Foto Nicolas Maeterlinck (Belga))

- PFAS Commission Flemish Parliament
- (June 2021- March 2022)
- PFAS Coordinator assigned by Flemish Government (Karl Vrancken)
- PFAS Technical working groups, involving several health and environmental authorities → collaboration/integrated approach!
- PFAS website: [PFAS-vervuiling | Vlaanderen.be]
- Beyond Zwijndrecht hotspot: several smaller hotspots in Flanders (fire foam contaminated sites, downstream users of PFAS industrial sites,….)

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Policy and societal impact PFAS crisis Zwijndrecht (Flanders)

- Following the results of PFAS serum in 796 levels in Flanders, the Flemish authorities forced end October 2021 3M temporally to stop all PFAS involving processes until 3M can prove emission is acceptable from health perspective (still in place today)

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Policy and societal impact PFAS crisis Zwijndrecht (Flanders)

- Action groups went to court → judge stopped road construction works in Antwerp (excavation of PFAS contaminated site) → precent for many infrastructure projects on Flanders!!

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- Since June 2021: precautionary measures announced to residents in Zwijndrecht:

Measure	< 1,5 km	1,5 – 3 km	3 – 5 km	5 – 10 km
No consumption of local eggs !!!	x	x	x	
Max. 1 local egg/week				x
Vulnerable groups: no consumption of local grown vegetabels	x	x		
General population : moderate consumption of local grown vegetables; mix with food from retail	x			
Always rince vegetables very good before consumption	x	x	x	
Avoid use of groundwater for drinking	x	x		
Avoid use of groundwater for irrigation of kitchen garden	x			

And similar measures at many other PFAS sites !!

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- Following no regret measures
- → local farmers affected!
  - 3M foresees compensation for farmers
- Societal concern!!
  - In Zwijndrecht

www.eikes.be

And many other PFAS affected sites (mapping of sites in Flanders)

HCB Scandal in Austria

HCB-SKANDAL

1000 Rinder nicht zu vermarkten

Görtschitztaler Bauern immer schwerer in Existenznöten, weil das Fleisch ihrer Tiere HCB-belastet und unverkäuflich ist.

Weil sich das Umweltgift Hexachlorbenzol in Fett einlagert, sind im Görtschitztal die Tiere von der HCB-Belastung besonders betroffen. Für die Bauern wird die Situation immer dramatischer, auch wenn seit Wochen intensiv am Austausch des Futters gearbeitet wird. Denn was mit den in den Ställen stehenden Tieren geschehen soll, weiß man noch nicht. Rund 1000 Rinder sind nicht zu vermarkten. Den dadurch für die Bauern entstehenden Schaden bezifferte Agrarreferent Landesrat Christian Benger (ÖVP) am Dienstag nach der Regierungssitzung mit 1,6 Millionen Euro.

20.000 Tonnen Futtermittel müssen im Görtschitztal getauscht werden.
Am Montag begann der Austausch des mit HCB belasteten Futters. Getauscht werden 20.000 Tonnen.

1000 cattle not marketable

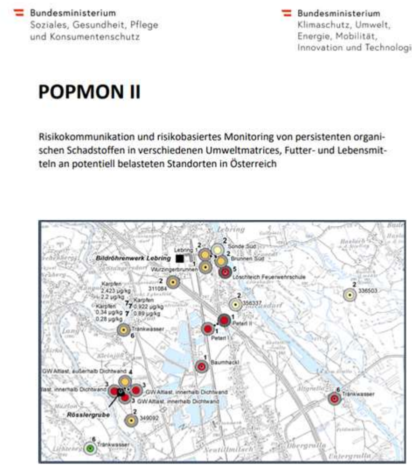
Farmers in Görtschitztal are facing increasing hardship because the meat of their animals is contaminated with HCB and cannot be sold. Because the environmental toxin hexachlorobenzene is stored in fat, animals in the Görtschitz Valley are particularly affected by HCB contamination. The situation is becoming more and more dramatic for the farmers, even though they have been working intensively on replacing the feed for weeks. For what is to happen to the animals standing in the stables is not yet known. About 1000 cattle cannot be marketed. On Tuesday, after the government meeting, Christian Benger (ÖVP), the regional councillor for agriculture, **estimated the resulting damage to the farmers at 1.6 million euros.**

20,000 tons of fodder have to be exchanged in the Görtschitz Valley.
On Monday, the exchange of HCB-contaminated fodder began. 20,000 tons will be exchanged.

Austria:
POPMON –project

Risk communication and risk-based monitoring of persistent organic pollutants in different environmental matrices, feed and food at potentially contaminated sites in Austria.

Policy recommendations:
improve cooperation between different authorities in cases that arise and,
if necessary, to establish **cross-sectoral coordination**: of different legal matters and areas of responsibility and to coordinate different ministries and Land authorities.
depending on the **escalation levels**, appropriate coordination at federal and state level:
routine activities – emergency – crisis management



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Publications > Keeping our water clean: the case of water contamination in the Veneto Region, Italy (2017)

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Keeping our water clean: the case of water contamination in the Veneto Region, Italy (2017)

Download

English (PDF, 9.9 MB)

2017, xii + 57 pages
ISBN 978 92 890 5246 7
This publication is only available online.

Perfluoroalkylated substances (PFAS) are highly resistant persistent compounds used for repelling oil, grease and water and protecting the surfaces of carpets and clothing; they are also found in fire-fighting foams. They have negative consequences for human health, although these are not fully established.

In 2013, PFAS contamination was found in the drinking-water in parts of the Veneto Region, Italy. This publication describes the experience of the Veneto Region in responding to this public health emergency. The challenges met were typical of those any public health authority might face in responding to a sudden and acute environmental health threat; thus, the lessons learnt in the Veneto Region in dealing with the incident will undoubtedly be useful to other countries facing similar health threats.

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PFAS Awareness Workshop in AT; February 2021, federal and regional authorities

„From Knowledge to action“: Teams WS, Use of Beekast- tool

In order to develop concrete approaches, the respective fields of action, challenges and necessary activities were worked out in four working groups to discuss open questions, necessary measures and identify responsible institutions.

Working groups:

- Drinking Water
- Foodstuff
- Hotspots
- Communication

- Nomination of measures/activities
- Prioritisation
- Further discussion and description of the 3 highest ranked measures/activities
- Workshop Report
- Follow up Workshop on Progress in autumn 2022

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SWEDEN


KEMI
Kemikalieinspektionen
Ange sökord
Lagar och regler
Bekämpningsmedel
Kontroll och tillsyn
Start / Kemiska ämnen och material / Högfluorerade ämnen – PFAS / PFAS-nätverk

PFAS-nätverk

PFAS- nätverket är ett nätverk som består av myndighetsföreträdare, forskare, länsstyrelser, kommuner, konsulter och företag. Syftet med nätverket är framför allt att dela kunskap, men också att försöka hitta lösningar för att komma till rätta med problemen kring PFAS och förhindra framtida problem.

Högfluorerade ämnen finns i marken och i dricksvattnet i flera svenska kommuner. Den stora spridningen av farliga, högfluorerade ämnen (PFAS) i samhället är ett omfattande samhällsproblem där flera aktörer måste samverka för att kunna komma till rätta med problemen. Kemikalieinspektionen och Livsmedelsverket har därför startat ett öppet nätverk för de som berörs av PFAS-problemet, vilket inkluderar myndigheter, forskare, länsstyrelser, kommuner och vattenproducenter. Sedan 2018 har också Naturvårdsverket gått in som arrangör.

Öppet nätverk

Nätverket är öppet för alla som berörs av problemen med PFAS, till exempel myndigheter på olika nivåer i samhället, konsulter, forskare och företag som har kunskap om och erfarenhet av PFAS.

Kontaktpersoner för nätverket

Om du vill veta mer om nätverket kan du höra av dig till någon av kontaktpersonerna.

PFAS Network

The PFAS Network is a network of government representatives, researchers, county councils, municipalities, consultants and companies. The aim of the network is primarily to share knowledge, but also to try to find solutions to overcome the problems associated with PFAS and prevent future problems.

Open network

The network is open to all those affected by the PFAS problem, such as authorities at different levels of society, consultants, researchers and companies with knowledge and experience of PFAS.

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Austria: Salzburg Airport

For five decades, toxic substances from the airport fire brigade's extinguishing foam leaked into the groundwater around Salzburg Airport.

The problem became known internally in 2018 and was made public in 2022.

The residents' association is outraged.

VIDEO SN PLUS ALTLAST

Wirbel um Löschschaum am Airport Salzburg: Anrainerverband spricht von Intransparenz

Quelle
SN

Dienstag
29. März 2022 12:12 Uhr

0 Kommentare

Artikel drucken

Fünf Jahrzehnte lang sickerten giftige Substanzen aus dem Löschschaum der Flughafenfeuerwehr in das Grundwasser rund um den Salzburg Airport. Das Problem wurde 2018 intern bekannt und 2022 öffentlich bekanntgegeben. Der Anrainerverband ist empört.

Die Betriebsfeuerwehr des Salzburger Flughafens: Mittlerweile wird nur noch mit Wasser geübt. Doch bis 2018 kam fallweise auch Löschschaum zum Einsatz. Und der hat das Grundwasser verunreinigt.

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DENMARK: ● Guidance for general practitioner doctors about citizens exposed to PFAS; ● To you who have been exposed to PFAS

Danish Board of health: January 2022

- Facts about PFAS
- Exposure
- Absorption
- Half-life in the blood
- Health Effects

Handling in general practice of citizens who have been exposed to PFAS

- Laboratory Tests
- Clinical examination
- Counseling
- Advice on pregnancy
- Advice on breastfeeding
- Advice regarding children
- Cancer concern Counseling
- Questions and Answers

https://www.sst.dk/da/Viden/Miljoe/Miljoe-og-sundhed/PFAS

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SWEDEN


KEMI
Kemikalieinspektionen
Ange sökord
Lagar och regler
Bekämpningsmedel
Kontroll och tillsyn
Start / Kemiska ämnen och material / Högfluorerade ämnen - PFAS / Guide om PFAS

Guide om PFAS

PFAS är syntetiskt framställda kemikalier. Ibland kallas de även för högfluorerade ämnen. PFAS finns i miljön och har förorenat dricksvattnet på flera ställen i Sverige. Föroreningarna berör många aktörer i samhället och många myndigheter är involverade. Den här guiden är ett försök att guida dig rätt bland flera myndigheters information om PFAS.

Guiden har tagits fram av myndighetsnätverket för PFAS-frågor där Kemikalieinspektionen, Livsmedelsverket, Naturvårdsverket, Myndigheten för samhällsskydd och beredskap (MSB), Sveriges geologiska undersökning (SGU), Statens geotekniska institut (SGI), Havs- och vattenmyndigheten, Försvarsinspektören för Hälsa och Miljö och Länsstyrelsen ingår. Guiden uppdateras i takt med arbetet i myndighetsnätverket.

Guide to PFAS

PFAS are synthetically produced chemicals. They are sometimes called highly fluorinated substances. PFASs are found in the environment and have contaminated drinking water in several places in Sweden.

Pollution affects many actors in society and many authorities are involved.

This guide is an attempt to guide you through the information on PFAS provided by several authorities.

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Thanks !!!

- To all collaborating PFAS hotspot network members

REGION SJÆLLAND
HOLBÆK SYGEHUS
- vi er til for dig

IPASUM
Institut und Poliklinik für Arbeits-, Sozial- und Umweltmedizin

FAU
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
MEDIZINISCHE FAKULTÄT

UBEP

TOGETHER WE MAKE TOMORROW MORE BEAUTIFUL
OVAM

LUND UNIVERSITY

KØBENHAVNS UNIVERSITET

umweltbundesamt

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Thank you for your contribution!

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