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Contaminants in blood and urine from young children in Sweden

Results from the national dietary survey Riksmaten Young Children

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Preface

The present report summarises the results from analysis of contaminants in blood and urine samples from participants in the dietary survey Riksmaten Young Children (Riksmaten småbarn 2021-24). These biomonitoring data provide unique information on total exposure to contaminants from all sources, including food, in Swedish children. The results will be used further in risk assessments of contaminants in food by the Swedish Food Agency (Livsmedelsverket). Data from the project is also part of the national health-related environmental monitoring at the Swedish Environmental Protection Agency (Naturvårdsverket). The results in this report may also be useful for experts working with risk assessment and risk management in other organizations at the national or regional level.

Riksmaten Young Children was carried out by the Swedish Food Agency. The sampling of blood and urine, analyses of contaminants and writing of this report were partly financed by the health-related environmental monitoring programme at the Swedish Environmental Protection Agency (agreement number 215-21-005 and 215-23-007).

Sanna Lignell (Unit of Toxicology) and Helena Bjermo (Unit of Nutrition) at the Division of Risk and Benefit Assessment were responsible for the statistical analyses and the writing of this report. Numerous colleagues, both at the Swedish Food Agency and at other institutions, have made valuable contributions to the study and to this report (see section Contributors).

Livsmedelsverket / Swedish Food Agency

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February 2025

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1. Abbreviations[1]

AM	Arithmetic mean
ANOVA	Analysis of variance
ATDSR	Agency for Toxic Substances and Disease Registry
BE	Biomonitoring Equivalent
bw	Body weight
DiNCH	Di-iso-nonyl-cyclohexane-1,2-dicarboxylate
EFSA	European Food Safety Authority
EOM	Environmental and Occupational Medicine
GM	Geometric mean
HBM I/II	Human biomonitoring assessment value I/II
HBM4EU	Human Biomonitoring for Europe (a large European biomonitoring project)
HBM-GV	Human biomonitoring guidance value
HCT	4-hydroxy-chlorothalonil
IARC	International Agency for Research on Cancer
ICP-MS	Inductively coupled plasma mass spectrometry
LC-MS/MS	Liquid chromatography-tandem mass spectrometry
LOD	Limit of detection
NICE	Nutritional Impact on the Immunological Maturation during Childhood in relation to the Environment (mother-child cohort in northern Sweden)
PAH	Polycyclic aromatic hydrocarbon
perc	Percentile
PFAS	Per- and polyfluoroalkyl substances
PFCA	Perfluoroalkyl carboxylic acids
PFSA	Perfluoroalkyl sulfonic acids
RMA	Riksmaten adolescents 2016-17 (Swedish dietary survey in adolescents)
ΣPFAS4	sum of four PFAS: PFOA, PFNA, PFHxS and tot-PFOS
SD	Standard deviation
TDI	Tolerable daily intake
TWI	Tolerable weekly intake

[1] In addition to the abbreviations listed here, see Table 1 and Table 2 for abbreviations of individual per- and polyfluoroalkyl substances and organic contaminants in urine.

2. Sammanfattning

Svenska småbarn har generellt låga halter av kemiska föroreningar i kroppen som sannolikt inte utgör en risk för hälsan. Exponeringen för bly, per- och polyfluorerade alkylsubstanser (PFAS) och bisfenol A är dock något högre än vad som är önskvärt.

Detta visar Livsmedelsverkets biomonitorering av kemiska föroreningar i blod och urin, från matvaneundersökningen Riksmaten småbarn. Småbarn är en särskilt viktig grupp att studera, eftersom de kan vara mer känsliga för de skadliga effekterna av toxiska kemikalier än vuxna.

Resultaten ger en unik översikt över den totala exponeringen från alla källor i en nationellt representativ grupp av svenska 1,5- och 4-åringar. Riksmaten småbarn är en tvärsnittsstudie där Livsmedelsverket undersöker matvanorna hos barn som är 9 månader, 1,5 år och 4 år gamla. I den här rapporten ingår de 593 barn som deltog i oktober 2021 till maj 2023 och som lämnade blodprov eller urinprov. Av dem var 305 barn 1,5 år och 288 var 4 år. Alla bodde i, eller inom 50 km från, Umeå, Uppsala, Stockholm, Örebro, Linköping, Göteborg eller Lund.

Vi analyserade ett brett spektrum av ämnen, som man främst får i sig från mat och dricksvatten:

- metaller i helblod
- PFAS i serum
- en nedbrytningsprodukt av pesticiden klortalonil (4-hydroxy-klortalonil) i serum
- flera organiska kontaminanter i urin, bland annat bisfenoler samt metaboliter av mjukgörare, fosforbaserade flamskyddsmedel, pesticider och doftämnen.

Resultat och slutsatser

Ämnen ur alla ämnesgrupperna fanns i proverna från de flesta av barnen. Halterna låg inom de intervall som kunde förväntas och var generellt jämförbara med nivåerna som har uppmätts i andra studier.

Att göra en fullständig värdering av riskerna med de halter som uppmätts ingår inte i syftet med den här rapporten. För flera av ämnena[2] jämförde vi dock resultaten med olika typer av hälsobaserade bedömningsvärden. För halter som är lägre än bedömningsvärdet, är det osannolikt med negativa hälsoeffekter. Våra resultat tyder på att halterna som de flesta svenska barn har i sina kroppar, sannolikt inte utgör en risk för hälsan.

[2] Kvicksilver, bly, PFAS, några ftalat- och DiNCH-metaboliter, bisfenol A, pesticidmetaboliten 3-fenoxybensoesyra samt det antibakteriella ämnet triklosan.

Vissa barn hade dock högre halter av bly eller PFAS än de hälsobaserade bedömningsvärdena. Halterna av bisfenol A i urinproverna bekräftade också vad Efsa[3] tidigare har konstaterat, det vill säga att vi får i oss för mycket bisfenol A. Detta understryker att det är viktigt att ytterligare minska exponeringen för bly, PFAS och bisfenol A, från alla källor.

Vi kan dessutom inte utesluta, att det finns vissa grupper av barn i Sverige som utsätts för en ännu högre exponering för kemiska föroreningar, än de barn som deltog i Riksmaten småbarn.

Metaller i helblod

Nästan alla barn hade mätbara halter i blodet av kadmium, kvicksilver, bly, arsenik, kobolt och mangan. Resultaten tyder på att svenska barns exponering för kvicksilver inte utgör en hälsorisk, baserat på nuvarande kunskaper. Halterna av kadmium låg inom det förväntade intervallet.

För bly, däremot, hade 10 procent av barnen halter högre än Efsas referenspunkt för ökad risk för påverkan på hjärnans utveckling hos foster och små barn. Liknande resultat har setts i andra studier av svenska barn. Detta understryker att det är viktigt att ytterligare minska exponeringen för bly, från alla källor.

PFAS i serum

Av PFAS uppmättes högst serumhalter av PFOS, PFOA och PFHxS[4]. 1,5-åringarna hade högre halter än 4-åringarna, vilket sannolikt beror på att exponeringen är högre under foster- och amningsperioden, jämfört med senare i livet.

Barnen från Uppsala och Stockholm hade högre halter av några PFAS, jämfört med barnen från de övriga regionerna. Anledningen är troligen att vissa delar av Uppsala och Stockholm har eller har haft förhöjda halter av PFAS i dricksvattnet.

Av 1,5-åringarna hade 4,5 procent halter som var högre än Efsas referenspunkt i riskvärderingen av ΣPFAS4[5]. Referenspunkten baseras på ökad risk för påverkan på vaccinationseffekten hos 1-åringar. Resultatet indikerar att en andel av barnen har exponerats för mer PFAS än vad som är önskvärt.

Under senare år har åtgärder vidtagits för att minska exponeringen för PFAS, och nya lägre gränsvärden för ΣPFAS4 i dricksvatten träder i kraft 2026. Detta kommer sannolikt att leda till att exponeringen minskar ytterligare.

[3] European Food Safety Authority, EU:s myndighet för livsmedelssäkerhet

[4] PFOS: perfluoroktansulfonsyra; PFOA: perfluoroktansyra; PFHxS: perfluorhexansulfonsyra

[5] Summan av PFOS, PFHxS, PFOA och PFNA (perfluornonansyra)

4-hydroxy-klortalonil i serum

4-hydroxy-klortalonil fanns i serum från alla barn. 1,5-åringarna hade högre halter än 4-åringarna. Liksom för PFAS beror det sannolikt på att exponeringen är högre under foster- och amningsperioden, än senare i livet.

Organiska kontaminanter i urin

De flesta av de organiska kontaminanterna fanns i majoriteten av urinproverna. Eftersom dessa ämnen är kortlivade och försvinner snabbt ur kroppen kan våra resultat tyda på att barnen utsätts för en kontinuerlig exponering.

Alla analyserade metaboliter av ftalater och DiNCH[6] fanns i nästa alla urinprover (>99 procent). Ftalatmetaboliten MnHxP[7] fanns i 99 procent av proverna, och har inte analyserats i svenska prover tidigare, enligt vad vi känner till. Kunskaperna är också begränsade om urinhalter av IPBA och TBBA[8] (metaboliter till doftämnena p-cymen och lysmeral). Vi kunde mäta dem i ungefär 90 procent av proverna. Det antibakteriella ämnet triklosan fanns i 25 procent av proverna.

Våra resultat indikerar ingen risk för negativa hälsoeffekter av exponeringen för ftalat- eller DiNCH-metaboliterna, pesticidmetaboliten 3-fenoxybensoesyra eller triklosan. Detta enligt vår jämförelse med hälsobaserade bedömningsvärden.

För bisfenol A däremot, tyder resultaten på att exponeringen är högre än vad Efsa anser vara tolerabelt. Exponeringen kommer dock sannolikt att minska, till följd av förbudet att använda bisfenol A i livsmedelsförpackningar i Europa, som gäller från 2025.

[6] Di-iso-nonyl-cyklohexan-1,2-dikarboxylat

[7] Monohexylftalat

[8] IPBA, 4-isopropylbensoesyra; TBBA, 4-tert-butylbensoesyra

3. Summary

Swedish young children generally have low levels of chemical contaminants in their bodies and such contaminants are thus unlikely to pose a risk to their health. However, exposure to lead, per- and polyfluoroalkyl substances (PFAS) and bisphenol A is somewhat higher than desirable.

This is shown in the Swedish Food Agency's biomonitoring of chemical contaminants in blood and urine in the dietary survey Riksmaten Young Children. Young children are a particularly important group to study, as they might be more sensitive to the adverse effects of toxic chemicals than adults.

The results provide a unique overview of the total exposure to chemical contaminants from all sources in a nationally representative group of Swedish 1.5- and 4-year-olds. Riksmaten Young Children is a cross-sectional study in which the Swedish Food Agency examines dietary habits in children aged 9 months, 1.5 years and 4 years. This report includes the 593 children who participated in the study in October 2021 to May 2023 and donated blood or urine samples. Of them, 305 were 1.5-year-olds and 288 were 4-year-olds. All children lived in, or within 50 km from, Umeå, Uppsala, Stockholm, Örebro, Linköping, Gothenburg or Lund.

In the samples, we analysed a wide range of substances that humans mainly are exposed to from food and drinking water:

- metals in whole blood
- PFAS in serum
- a metabolite of the pesticide chlorothalonil (4-hydroxy-chlorothalonil) in serum
- several organic contaminants in urine, including bisphenols and metabolites of plasticisers, organophosphate flame retardants, pesticides and fragrances, and others

Results and conclusions

In summary, we found measurable concentrations of substances from all investigated contaminant groups in the samples from most children in Riksmaten Young Children. The concentrations were generally comparable to those found in other studies and within the expected range.

Full risk assessments of the observed concentrations are beyond the aim of this report. However, for some of the substances we could compare the results with different types of human biomonitoring assessment values. For concentrations lower than an assessment value, adverse health effects are unlikely. Our results indicate that the levels of contaminants that most Swedish children have in their bodies probably do not pose any health risk.

However, some children exhibited higher concentrations of lead or PFAS than their human biomonitoring assessment values. Also, the urine concentrations of bisphenol A confirm the conclusion by EFSA[9] that bisphenol A exposure is too high. This underlines the importance of working towards further reducing exposure to lead, PFAS and bisphenol A, from all sources.

In addition, we cannot exclude the possibility that there are certain groups of children in Sweden with higher exposure to chemical contaminants than the participants in Riksmaten Young Children.

Metals in whole blood

Almost all participants had detectable concentrations of cadmium, mercury, lead, arsenic, cobalt and manganese in their blood. The results suggest that the exposure of Swedish children to mercury does not pose a health risk, based on current knowledge. Cadmium concentrations were within the expected range.

By contrast, 10% of the children had blood lead concentrations above EFSA's reference point for increased risk of impact on brain development in foetuses and young children. Similar results have been seen in other studies of Swedish children. This underlines the importance of further reducing exposure to lead, from all sources.

PFAS in serum

Among the analysed PFAS, the substances PFOS, PFOA and PFHxS[10] were found to have the highest serum concentrations. 1.5-year-olds had higher levels than 4-year-olds, probably due to higher exposure during the foetal and breastfeeding periods, compared to exposure later in life.

The children from Uppsala and Stockholm had higher levels of some PFAS than children from the other regions. The reason is probably that some parts of Uppsala and Stockholm have or have had elevated levels of PFAS in drinking water.

In total, 4.5% of the 1.5-year-olds had serum concentrations of ΣPFAS4[11] higher than EFSA's reference point in the risk assessment of ΣPFAS4. The reference point is based on increased risk of effects on vaccination response in 1-year-olds. This indicates that some of the children have had greater PFAS than what is desirable, during the foetal period and the first years of life.

In recent years, measures have been taken to reduce exposure to PFAS, and new lower maximum limits for ΣPFAS4 in drinking water will enter into force in 2026. This will likely lead to an ongoing reduction of exposure.

[9] European Food Safety Authority

[10] PFOS, perfluorooctane sulfonic acid; PFOA, perfluorooctanoic acid; PFHxS, perfluorohexane sulfonic acid

[11] Sum of PFOS, PFHxS, PFOA and PFNA (perfluorononanoic acid)

4-hydroxy-chlorothalonil in serum

4-hydroxy-chlorothalonil was found in serum from all children. The 1.5-year-olds had higher levels than 4-year-olds. As for PFAS, this is probably due to a higher exposure during the foetal and breastfeeding periods than in later periods in life.

Organic contaminants in urine

Most of the organic contaminants were found in a majority of the urine samples. As these substances are short-lived and quickly disappear from the body, our results may indicate that children are subject to continuous exposure.

All analysed metabolites of phthalates and DiNCH[12] could be detected in almost all urine samples (> 99%). The phthalate metabolite MnHxP[13] was present in 99% of the samples, and this metabolite has not been analysed in Swedish samples earlier, as far as we know. There is also limited knowledge about urine levels of IPBA and TBBA[14] (metabolites of the fragrances p-cymene and lysmeral). These substances could be detected in approximately 90% of the samples. The antibacterial substance triclosan was detected in 25% of the samples.

Comparisons with human biomonitoring assessment values indicate no risk of adverse health effects in the children from exposure to metabolites of phthalates or DiNCH, the pesticide metabolite 3-phenoxybenzoic acid or triclosan. On the other hand, for bisphenol A, the results suggest that the exposure is higher than what EFSA considers tolerable. However, exposure to bisphenol A is likely to decrease as a result of the ban in use of bisphenol A in food contact materials in Europe, which applies from 2025.

[12] Di-iso-nonyl-cyclohexane-1,2-dicarboxylate

[13] Monohexyl phthalate

[14] IPBA, 4-isopropylbenzoic acid; TBBA, 4-*tert*-butylbenzoic acid

4. Background and aim

Dietary data constitute an important scientific basis for risk and benefit assessments as well as for the development of risk management measures such as dietary advice, control programmes and food regulations. The Swedish Food Agency therefore regularly carries out national dietary surveys to gather information on dietary intake. The collected data are used to calculate food and nutrient intakes as well as to estimate exposure to unwanted substances via food, for example. In the three most recent dietary surveys, Riksmaten Adults 2010–11, Riksmaten Adolescents 2016–17 and Riksmaten Young Children 2021-24, the collection of dietary data was complemented by sampling of blood and urine in participant subgroups. The samples were used for analysis of markers for nutritional status and contaminants. Human biomonitoring data are important for assessing nutritional status and human exposure to contaminants that could negatively affect health.

The aim of this report is to summarise results from the biomonitoring of contaminants in blood and urine from participants in the dietary survey Riksmaten Young Children. Contaminant concentrations are described, and when possible, compared with different types of human biomonitoring assessment values. Differences in contaminant concentrations between geographical regions, age groups (1.5- and 4-year-olds) and genders are also investigated. More in-depth statistical analyses of other factors that may influence exposure, e.g., food consumption, lifestyle and socioeconomic factors, will be performed later and is therefore not within the scope of this report.

The substances/substance groups that have been analysed are metals in whole blood, per- and polyfluoroalkyl substances (PFAS) and 4-hydroxy-chlorothalonil (a metabolite of the fungicide chlorothalonil) in serum and organic contaminants (phthalate metabolites, organophosphate flame-retardant metabolites, bisphenols, pesticide metabolites and others) in urine. Most of these chemicals are of interest for the Swedish Food Agency due to their presence in food and/or drinking water. The substances were also chosen because they are among the contaminants that are regularly monitored within the national health-related environmental monitoring programme run by the Swedish Environmental Protection Agency.

To the best of our knowledge, Riksmaten Young Children is to date the largest nationally representative study on diet and body burden of contaminants in Swedish children. The data in this report therefore provide unique information on exposure to contaminants from all sources, including food, in Swedish children. The studied population is of particular interest because young children might be more sensitive to exposure to toxic chemicals than adults.

5. Materials and methods

5.1 Study design and population

The study population for the present report is a subgroup of 1.5- and 4-year-olds in Riksmaten Young Children, from whom blood and urine was collected. Riksmaten Young Children is a national cross-sectional dietary survey of young children aged 9 months, 1.5 years and 4 years. Details of the study design and sampling procedures are described in Bjermo et al. (2024). The 4-year-olds were recruited during autumn 2021 and spring 2022 and the 1.5-year-olds during autumn 2022 and spring 2023. The survey included a mandatory web-based food diary (2 days) and a questionnaire. Optional parts of the study included physical activity assessment as well as blood, urine, and stool sampling in subgroups. Ethical approval for the study was obtained from the Swedish Ethical Review Authority (2020-05293).

Register-based random samples were drawn by Statistics Sweden (Statistiska centralbyrån, SCB) to represent 1.5- and 4-year-olds in Sweden. The samples were stratified based on the level of education achieved, at household level. The goal was to include approximately 1000 participants per age group in the dietary survey, of which 300 per age group would also donate blood and urine. The sampling was conducted at Environmental and Occupational Medicine (EOM) clinics. Therefore, only children living within 50 km of one of Sweden's seven EOM clinics were asked to donate blood and urine samples. Since we expected that too few participants would live close enough to an EOM clinic, we oversampled this population by 15%. The oversampling was proportional to the number of children aged 0–4 y living in each EOM region. The EOM clinics are geographically located across Sweden (Umeå, Uppsala, Stockholm, Örebro, Linköping, Gothenburg, Lund) (Figure 3) providing a nationally distributed sample. For 4-year-olds, a total sample of 7800 children who turned four between August 2021 and May 2022 were drawn. 4544 of these children lived near an EOM clinic and were asked to participate in the biomonitoring part of the survey. Since participation rates for 4-year-olds turned out to be lower than expected, the sample size for 1.5-year-olds was increased to 9000 children turning 18 months between September 2022 and May 2023. Among these, 5506 children lived near an EOM clinic and were asked to donate blood and urine.

Children were invited to participate in the study by letter to their legal guardians. The guardians could choose to participate in one or more parts of the survey and confirmed their choice and identity with digital identification (BankID) or with codes included in the invitation letter. Guardians who did not respond to the invitation were reminded by phone calls or text messages up to four times or with a reminder letter if the phone number was unknown. Both guardians (if applicable) needed to consent before participation.

A study flow chart of the recruitment and participants in the biomonitoring (blood and urine) subgroup of Riksmaten Young Children is presented in Figure 1. Of the 5,506 children in the

sample of 1.5-year-olds, 349 agreed to participate in the biomonitoring part of the study, and 305 (5.5%) finally completed the dietary survey and donated blood and/or urine (blood N=294, urine N=65; urine was only sampled in 1,5-year-olds who did not use diapers). For the 4-year-olds, 316 out of 4,544 agreed to participate, and 288 (6.3%) completed the dietary survey and donated blood and/or urine (blood N=273, urine N=276).

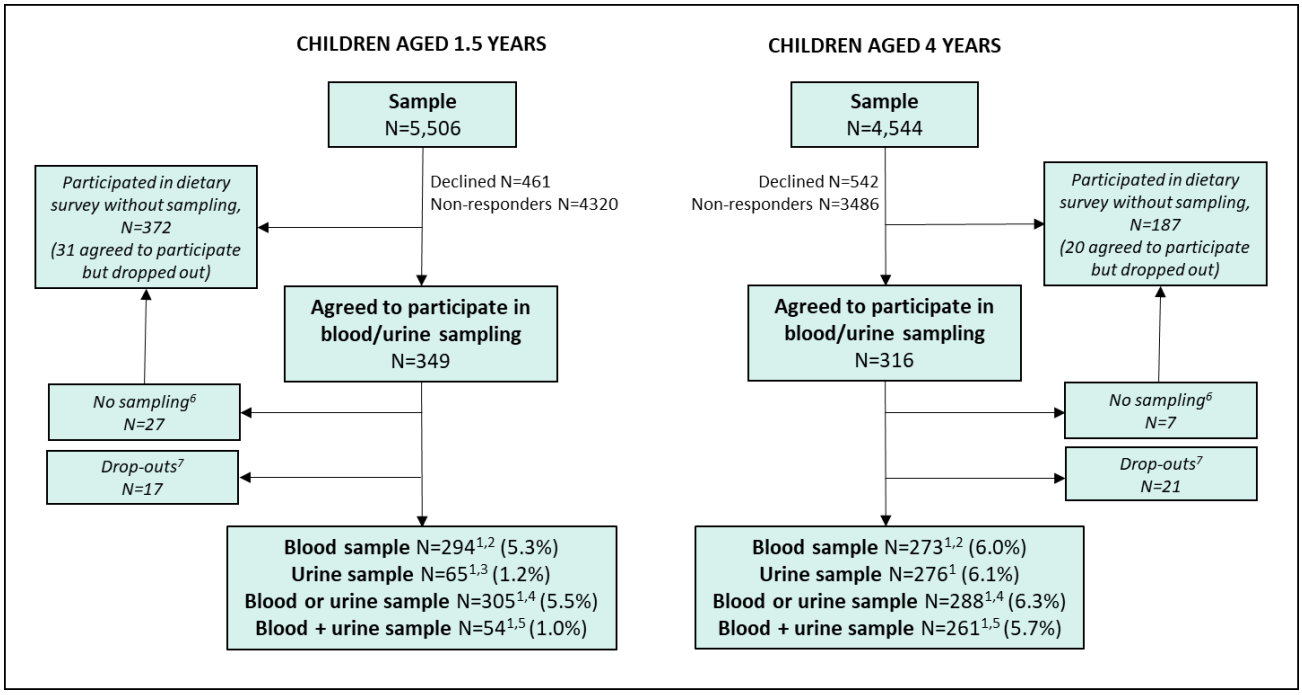

Figure 1. Study flow chart of the biomonitoring subgroup (blood and urine) of Riksmaten Young Children.

[1]The participants also completed the dietary survey (food diary and questionnaire), except for one participant (4-year-old) that did not complete the questionnaire.

[2]At least one of the sample matrices plasma, serum and/or whole blood.

[3]The number of urine samples in 1.5-year-olds is small because urine was only sampled in children who did not use diapers.

[4]At least one of the sample matrices plasma, serum and/or whole blood AND/OR a urine sample.

[5]At least one of the sample matrices plasma, serum and/or whole blood AND a urine sample.

[6]Due to unsuccessfull sampling (N=27 1.5-year-olds and N=2 4-year-olds) *or* could not attend the sampling because of illness, declined sampling later etc.

[7]Never started their participation or did not complete any part of the study

5.2 Sampling

Blood and urine samples were collected at clinics run by regional divisions of EOM. The EOM clinic in Uppsala could not participate, so blood and urine from children living near Uppsala were collected by a nurse employed at the Swedish Food Agency. The participants were invited to the clinic for sampling when they had completed the first day of the 2-day food diary. Non-fasting venous blood was collected from the back of the hand or the bend of the arm by registered nurses or other certified personnel. The site was anesthetized using a

patch with Lidocain and Prilocain. Up to 12.5 mL blood was collected (6 mL for serum, 4.5 mL for plasma, 2 mL whole blood). The tubes for serum and plasma were centrifuged (2200 G for 10 minutes) after at least 30 minutes (and maximum 5 hours), and serum and plasma were pipetted into aliquots. Whole blood samples were pipetted to aliquots without being centrifuged. The participants were asked to collect a urine sample in a 50 mL tube at home the same morning as the EOM clinic visit. If it wasn't possible to collect the urine directly in the tube it was also allowed to pour urine into the tube from a potty. The urine sample was brought to the clinic where it was aliquoted. Urine was not collected from children using diapers. All samples (blood and urine) were stored at -80°C at the EOM before transportation to the Swedish Food Agency, where they were stored at -80°C until analysis.

5.3 Chemical analyses

5.3.1 Metals in whole blood

Analyses of metals (cobalt, arsenic, cadmium, mercury, lead and manganese) in whole blood were performed at the Institute of Environmental Medicine, Karolinska Institutet, Stockholm. Total mercury in whole blood can be used as a proxy for methylmercury exposure but may slightly overestimate the exposure compared to concentrations in red blood cells because of minor presence of inorganic mercury (Berglund et al., 2005). Notably, the total arsenic concentration in blood is a mixture of both organic and inorganic arsenic.

The concentrations were measured using inductively coupled plasma mass spectrometry (ICP-MS; Agilent 7900, Agilent Technologies, Tokyo, Japan). Prior to the ICP-MS analyses, the blood samples were diluted 1:20 in an alkali solution (2% (w/v)1-butanol, 0.05% (w/v) EDTA, 0.05% (w/v) Triton X-100, 1% (w/v) NH4OH and 20 mg/L internal standard) and vortex mixed, sonicated for 5 minutes and thereafter centrifuged at 1000 rpm for 2 minutes (MSE centrifuge, Super Minor, MSE (UK) Ltd, London, England) (Lu et al., 2015b). The limit of detection (LOD) was calculated as three times the standard deviation of the blank concentrations for each element and was determined in each batch of samples. The highest LOD for each element is presented in Table 4.Quality control within and between different runs was ensured by measuring two commercial reference materials of whole blood. In general, there was a very good agreement between the obtained and the recommended values for all metals (Appendix 1, Table A1:1).

5.3.2 Per- and polyfluoroalkyl substances and 4-hydroxy-chlorothalonil in serum

The analyses of PFAS and 4-hydroxy-chlorothalonil in serum were performed at the Division of Occupational and Environmental Medicine at Lund University. Serum samples were analysed for PFAS and 4-hydroxy-chlorthalonil (HCT) using liquid chromatography-tandem mass spectrometry (LC-MS/MS; QTRAP 6500+; AB Sciex, Framingham, MA, USA) according to Norén et al. (2021) and Krais et al. (2024), respectively. Briefly, 100 µL serum were added with isotopically labelled internal standards for all compounds except for PFPeS and PFHpS. Acetonitrile was added, and the samples were shaken vigorously for 30 min to precipitate proteins and thereafter centrifuged. The PFAS included in the analytical method were ten perfluoroalkyl carboxylic acids (PFCAs) and six perfluoroalkyl sulfonic acids (PFSAs) (Table 1). PFOS was separated into lin-PFOS and one isomer peak. The branched PFOS isomers were evaluated using a calibration curve of linear PFOS. Both linear and branched PFOS were evaluated using m/z transition 499-99. For higher specificity in the analysis of PFHxS, the ratios between three transitions (399-80, 99, and 119) were evaluated. The samples were analysed in randomized order.

The limit of detection (LOD) (Table 5 and Table 6) was defined as three times the standard deviation of the concentrations in chemical blank samples. The between-run precision was estimated by analysing PFAS and HCT in two homemade pooled serum samples as quality controls (QC) and accuracy in the PFAS-analyses was estimated by including two reference QCs from the EU-project Human Biomonitoring for Europe (HBM4EU). The coefficient of variation (CV) varied between 3 and 12% and there was good agreement between analysed and expected concentrations in the HBM4EU QCs (Appendix 1, Table A1:2 & Table A1:3). The laboratory participated successfully in the HBM4EU QA/QC program for PFAS analysis, and the German External Quality Assessment Scheme (G-EQUAS) coordinated by the University of Erlangen-Nuremberg, and currently participates in ICI/EQUAS for Partnership for the Assessment of Risks from Chemicals (PARC).

Table 1. Per- and polyfluoroalkyl substances analysed in serum samples from Riksmaten Young Children.

Compound	Abbreviation
Perfluoroalkyl carboxylic acids (PFCAs)	
Perfluorobutanoic acid	PFBA
Perfluoropentanoic acid	PFPeA
Perfluorohexanoic acid	PFHxA
Perfluoroheptanoic acid	PFHpA
Perfluorooctanoic acid	PFOA
Perfluorononanoic acid	PFNA
Perfluorodecanoic acid	PFDA
Perfluoroundecanoic acid	PFUnDA
Perfluorododecanoic acid	PFDoDA
Perfluorotridecanoic acid	PFTrDA
Perfluoroalkyl sulfonic acids (PFSAs)	
Perfluorobutane sulfonic acid	PFBS
Perfluoropentane sulfonic acid	PFPeS
Perfluorohexane sulfonic acid	PFHxS
Perfluoroheptane sulfonic acid	PFHpS
Total perfluorooctane sulfonic acid	tot-PFOS
Linear perfluorooctane sulfonic acid	lin-PFOS
Branched perfluorooctane sulfonic acid	br-PFOS
Perfluorodecanesulfonic acid	PFDS

5.3.3 Organic contaminants in urine

The analyses of organic contaminants in urine were performed at the Division of Occupational and Environmental Medicine at Lund University. Analytes and their abbreviations used in this report are listed in Table 2. Urine samples were analysed using LC-MS/MS (QTRAP 5500, 6500+; AB Sciex, Framingham, MA, USA) according to modified published methods (Berge et al. 2019; Gyllenhammar et al. 2017, Norén et al (2020)). Briefly, the samples are added with internal standards (when available), de-conjugated using β-glucuronidase and diluted prior to analysis. The samples were analysed in randomized order. LODs (Table 7 &Table 8) were defined as three times the standard deviation of the concentrations in chemical blank samples. The between-run precision was estimated by analysing two homemade pooled urine samples as QC 1&2 and accuracy was estimated by including two reference QCs from the G-EQUAS interlaboratory program. The CV and accuracy were acceptable and improved when specific internal standards were available (Appendix 1, Table A1:4 & Table A1:5). Due to large matrix effects and interferences, some

Table 2. Organic contaminants analysed in urine samples from Riksmaten Young Children.

Abbreviation used in this report (alternative abbreviations in parenthesis)	CAS	Full name of compound	Parent compound
Metabolites of phthalates and DiNCH			
MEP	2306-33-4	Monoethyl phthalate	Diethyl phthalate (DEP)
MnHxP (MnHexP)	68515-50-4	Monohexyl phthalate	Dihexyl phthalate (DHxP, DHexP)
MBzP	2528-16-7	Monobenzyl phthalate	Dibenzyl phthalate (DBzP)
MnBP	131-70-4	Mono-n-butyl phthalate	Di-n-butyl phthalate (DnBP)
MiBP	30833-53-5	Mono-iso-butyl phthalate	Di-i-butyl phthalate (DiBP)
5-oxo-MEHP (5-oxo, MEOHP)	40321-98-0	Mono-(2-ethyl-5-oxohexyl) phthalate	Di-ethylhexyl phthalate (DEHP)
5-OH-MEHP (5-OH, MEHHP)	40321-99-1	Mono-(2-ethyl-5-hydroxylhexyl) phthalate	Di-ethylhexyl phthalate (DEHP)
5-cx-MEPP (5-cx, MECPP)	40809-41-4	Mono-(2-ethyl-5-carboxypentyl) phthalate	Di-ethylhexyl phthalate (DEHP)
oxo-MiNP (MOiNP, 7-oxo, 7-oxo-MMeOP)	936022-00-3	Mono-(4-methyl-7-oxooctyl) phthalate	Di-iso-nonyl phthalate (DiNP)
OH-MiNP (MHiNP, 7-OH, 7-OH-MMeOP)	936021-98-6	Mono-(4-methyl-7-hydroxyloctyl) phthalate	Di-iso-nonyl phthalate (DiNP)
cx-MiNP (MCiOP, 7-cx, 7-cx-MMeHP)	936022-02-5	Mono-(4-methyl-7-carboxyheptyl) phthalate	Di-iso-nonyl phthalate (DiNP)
cx-MiDP (MCiNP, i-cx)	not available	Monocarboxyisononyl phthalate	Di-iso-decyl phthalate (DiDP)
OH-MPHP (MPHHP, MHPHP, 6-OH)	1372605-11-2	6-hydroxy monopropylheptylphthalate	Di-propylheptyl phthalate (DPHP)
cx-MiNCH	1637562-51-6	1,2-Cyclohexanedicarboxylic acid mono 4-methyl-7-carboxy-heptyl ester	Di-iso-nonyl-cyclohexane-1,2-dicarboxylate (DiNCH)
OH-MiNCH	1637562-52-7	2-(((Hydroxy-4-methyloctyl)oxy)carbonyl)cyclohexane carboxylic acid	Di-iso-nonyl-cyclohexane-1,2-dicarboxylate (DiNCH)
Organophosphate flame retardant metabolites			
BBOEP	14260-97-0	Bis(2-butoxyethyl) phosphate	Tris(2-butoxyethyl) phosphate (TBOEP)
BDCIPP	72236-72-7	Bis(1,3-dichloro-2-propyl) phosphate	Tris(1,3-dichloro-2-propyl) phosphate (TDCIPP)

Abbreviation used in this report (alternative abbreviations in parenthesis)	CAS	Full name of compound	Parent compound
DPP (DPHP)	838-85-7	Diphenyl phosphate	Tri-phenyl phosphate (TPP)
Bisphenols			
BPA	80-05-07	Bisphenol A	-
BPS	80-09-01	Bisphenol S	-
BPF (4,4-BPF)	620-92-8	4,4-Bisphenol F	-
Polycyclic aromatic hydrocarbon (PAH) metabolites			
2,3-PHE (2,3-OH-PH)	605-55- 0	Hydroxyphenanthrene (phenanthren-2-ol) (sum of 2-OH and 3-OH phenanthrene)	Phenanthrene
1-PYR (1-HP)	5315-79-7	1-Hydroxypyrene	Pyrene
Pesticide metabolites			
TCP	6515-38-4	3,5,6-trichloro-2-pyridinol	Chlorpyrifos
3-PBA	3739-38-6	3-phenoxybenzoic acid	Pyrethroids
OH-TEB	212267-64-6	Hydroxy-tebuconazole	Tebuconazole
OH-BOS	188425-85-6, 661463-87-2	Hydroxy-boscalid	Boscalid
Fragrance metabolites			
IPBA	536-66-3	4-isopropylbenzoic acid	several fragrances, including p-cymene
TBBA	98-73-7	4-*tert*-butylbenzoic acid	2-(4-tert-butylbenzyl) propionaldehyde, lysmeral, lilial
Other substances			
BP-3	131-57-7	Benzophenone-3 (oxybenzone)	-
TCS	3380-34-5	Triclosan	-

substances could not be determined in all samples. Matrix effects probably also caused a lower than usual precision in the analyses of e.g. phthalate metabolites. Some of the urine samples were sampled from potties, and this may have contributed to the matrix effects.

The laboratory participates bi-annually in G-EQUAS coordinated by the University of Erlangen-Nuremberg.

5.4 Statistical analysis

The statistical software package STATA (version 17), StataCorp LLC, was used to perform the statistical analyses. Concentrations below LOD (limit of detection) were replaced by LOD/√2 in all calculations. Urine concentrations of organic contaminants were adjusted to the mean urine density in the Riksmaten Young Children population (1.019 kg/L) according to Carnerup et al. (2006).

Chi2-tests were used to investigate if the distributions of participants between age groups or genders differed between regions (EOM clinics).

Concentrations of contaminants are described by number of samples and percentages with concentrations below LOQ or LOD, arithmetic mean (AM), standard deviation (SD), geometric mean (GM), 5^{th} percentile, median and 95^{th} percentile.

Differences in concentrations between age groups (1.5- and 4-year-olds), genders (boys and girls) and geographical regions were investigated for compounds with concentrations above LOD in at least 30% of the samples using analysis of variance (ANOVA). All three factors (age group, gender, region) were included in the same model. The classification of gender was based on personal identity number. Region was defined according to the location of the EOM clinic where the samples were donated (Umeå, Uppsala, Stockholm, Örebro, Linköping, Gothenburg, Lund). All ANOVA tests were performed on natural log-transformed contaminant concentrations to normalize the distribution. Tukey's multiple comparison test was used to investigate differences between regions and the results for regions are reported as back-transformed least square means with 95% confidence intervals (in bar-charts).

5.5 Comparisons with human biomonitoring assessment values

When possible, the contaminant concentrations were compared with different types of human biomonitoring assessment values to be able to discuss health risks in the population. The assessment values that we used were for example Human biomonitoring assessment values (HBM I/II values) derived by the German Human Biomonitoring Commission (Apel et al., 2017), Human biomonitoring guidance values (HBM-GVs) derived within the European biomonitoring program HBM4EU (Human Biomonitoring for Europe) (Apel et al., 2020), Biomonitoring Equivalent values (BE-values) (Angerer et al., 2011, Hays et al., 2008a) and reference points used in EFSA's (European Food Safety Authority) risk assessments. The definitions of these assessment values are given in the text in connection with their use.

6. Results

6.1 Characteristics of the study population

The distribution of participants according to gender, sampling year, region, type of municipality, household education level and parents' birth country is presented in Table 3, and the distribution between sampling months is presented in Figure 2A. The median/mean number of days between dietary registration and blood and urine sampling was 32/42. At sampling, the mean age of the 1.5-year-olds was 1.6 years (range 1.4-2.0), and the mean age of the 4-year-olds was 4.2 years (range 4.0-4.7). There were no differences in distribution of participants between age groups (p=0.40) or genders (p=0.19) between the regions (Figure 2B).

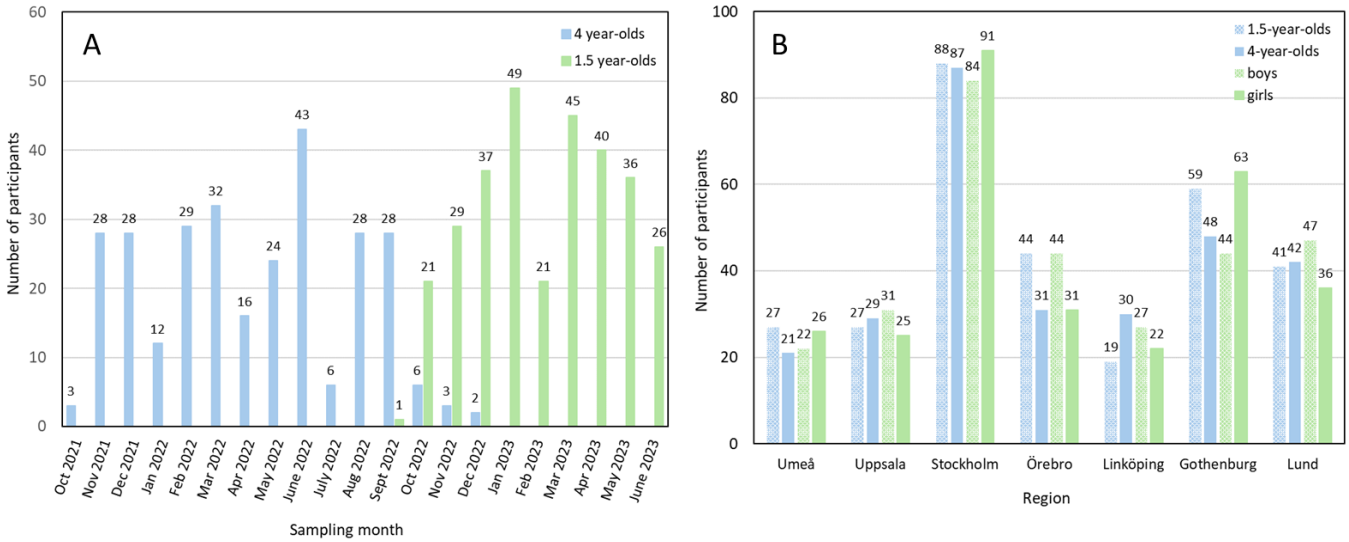

Figure 2. Distribution of participants in Riksmaten Young Children between (A) sampling months in different age groups and (B) age groups and genders in different regions.

Compared with the total Swedish population (Bjermo et al., 2024), participation rates were lower in families where both parents were born outside Sweden and in families with parents not having a university degree. In addition, there were very few participants living in smaller towns/urban areas and rural municipalities. That is however expected since only children living in municipalities within 50 km of the EOM clinics were asked to participate in sampling of blood and urine and the EOM clinics are located in large cities and medium-sized towns. The participants were distributed between the regions in proportions approximately reflecting the distribution of all Swedish children aged 0-4 years in 2022 (Table 3, Figure 3). However, participation rate was slightly lower in Linköping and Lund and higher in Stockholm and Örebro compared to the overall participation rate.

Table 3. Main characteristics of the participants in the Riksmaten Young Children subgroup that donated blood and/or urine (N=593).

	1.5-year-olds (N=305)		4-year-olds (N=288)	
	N	%	N	%
Gender[1]				
Girl	156	51	138	48
Boy	149	49	150	52
Sampling year				
2021	-	-	59	20
2022	88	29	229	80
2023	217	71	-	-
Parents' birth country[2]				
Both or only parent born in Sweden	230	75	220	76
One parent born in Sweden, one outside Sweden	46	15	49	17
Both or only parent born outside Sweden	21	7	18	6
Missing or incomplete data	8	3	1	0.3
Household education[3]				
At least one parent with higher education (>12 years)	279	91	258	90
Parents without higher education (≤12 years)	26	9	30	10
Type of municipality[4]				
Large cities and municipalities near large cities	164	54	161	56
Medium-sized towns and municipalities near medium-sized towns	132	43	126	44
Smaller towns/urban areas and rural municipalities	9	3	1	0.3
Region[5]				
Umeå	27	9	21	7
Uppsala	27	9	29	10
Stockholm	88	29	87	30
Örebro	44	14	31	11
Linköping	19	6	30	10
Gothenburg	59	19	48	17
Lund	41	13	42	15

[1]According to personal identity number [2]According to questionnaire [3]Based on register data provided by Statistics Sweden. [4]Classification of Swedish municipalities by the Swedish Association of Local Authorities and Regions was based on registered address at the time of sampling for the guardian who answered the questionnaire. [5]Defined according to the location of the EOM-clinic where the samples were donated.

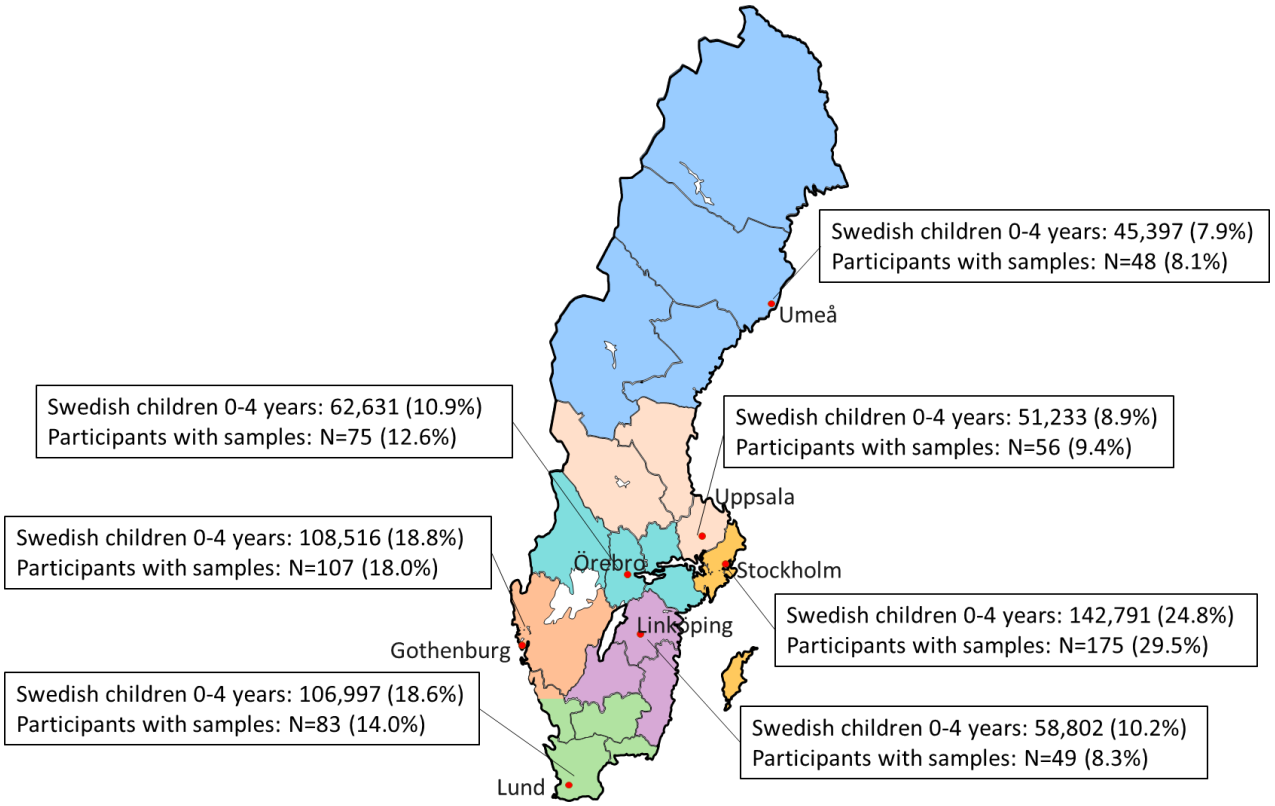

Figure 3. Number of participants in Riksmaten Young Children providing blood and/or urine samples (N=593), and the Swedish population of children aged 0-4 years (N=576,367) in 2022 (Statistics Sweden, 2024) per geographical region. Percent of total is given in parenthesis. All participants lived within 50 km of the city where the EOM-clinic is situated, i.e. Umeå, Uppsala, Stockholm, Örebro, Linköping, Gothenburg and Lund.

6.2 Metals in whole blood

6.2.1 Concentrations and comparisons with human biomonitoring assessment values

Metals are found in the environment due to their natural presence, but the levels may be elevated because of human activities. Some metals (e.g. iron and manganese) are essential for humans and have important physiological functions while others, like cadmium, mercury, lead and arsenic (semi metallic), are toxic to humans. Humans are exposed to metals from the environment or by ingestion of contaminated food or drinking water.

The number of whole blood samples available for analysis of metals was 538 (1.5-year-olds: N=269, 4-year-olds: N=269). The metals were analysed as ng/g whole blood (µg/kg), and obtained concentrations were converted to µg/L whole blood by multiplication with specific gravity for whole blood (1.055) (Lentner, 1981).

Concentrations of metals in all samples and in each age group are presented in Table 4. The median concentration of **cadmium (Cd)** in whole blood from 4-year-olds in the present study (0.14 µg/L) was higher than in 4-year-olds from the birth-cohort NICE (Nutritional Impact on the Immunological Maturation during Childhood in relation to the Environment) in northern Sweden sampled in 2019-2022 (median: 0.06 µg/L, estimated from concentrations in erythrocytes) (Vahter et al., 2024). The reason for this difference is unknown, but it is possible that there are geographical differences in the exposure to cadmium among children in Sweden. In the present study, blood Cd concentrations among children in Umeå (northern Sweden) were indeed lower than concentrations among children in Stockholm, Gothenburg and Lund (see section 6.2.3 and Figure 4). The mean Cd concentrations in 4-year-olds in the present study (AM: 0.15 µg/L, GM: 0.13 µg/L) were similar or somewhat higher than those observed in 8- to 11-year-olds in Landskrona sampled in 2019 (GM: 0.09 µg/L) (Lundh et al., 2020), in children in school grade 2 to 4 sampled in Lessebo in 2017 (GM: 0.09 µg/L) (Mattisson et al., 2018) and in children in school grade 5 participating in the national dietary survey Riksmaten adolescents 2016-17 (RMA) (AM: 0.10 µg/L) (Livsmedelsverket & Naturvårdsverket, 2020). We could not find any Swedish Cd data on children around 1.5 years of age.

There is no risk assessment of Cd specifically for children. In current health risk assessments of long-term Cd exposure in adults, the kidney is the critical organ (EFSA, 2009). Health-based reference points for Cd in the general population are mainly based on Cd in urine because this is regarded as a better measure of long-term exposure and the cumulative amount in the kidneys than Cd in blood (Lamkarkach et al., 2021). However, in a risk assessment

Table 4. Concentrations (µg/L) of metals in whole blood in Swedish 1.5- and 4-year-olds (N=538, whereof 269 1.5-year-olds and 269 4-year-olds) participating in Riksmaten Young Children. Concentrations and LODs were converted from µg/kg to µg/L by multiplication with specific gravity for whole blood (1.055). Concentrations below LOD were replaced by LOD/√2 in the calculations.

Metal	LOD	% of samples <LOD	Age group	AM	SD	GM	5th perc	Median	95th perc	p[1]
Cd	0.021	3.5	Both	0.12	0.08	0.09	0.03	0.10	0.26	
			1.5 years	0.09	0.07	0.07	<LOD	0.07	0.21	
			4 years	0.15	0.08	0.13	0.05	0.14	0.28	<0.001
Hg	0.089	2.2	Both	1.10	0.71	0.85	0.16	0.99	2.38	
			1.5 years	1.08	0.73	0.80	0.11	0.99	2.50	
			4 years	1.12	0.69	0.90	0.24	0.99	2.35	0.072
Pb	0.048	0	Both	7.51	4.22	6.67	3.26	6.44	15.44	
			1.5 years	7.86	4.65	6.89	3.24	6.62	16.45	
			4 years	7.16	3.72	6.45	3.41	6.14	12.89	0.077
As	0.054	1.1	Both	2.86	4.55	1.61	0.39	1.46	9.27	
			1.5 years	2.78	4.63	1.57	0.42	1.42	10.00	
			4 years	2.94	4.47	1.65	0.34	1.57	8.82	0.585
Co	0.039	1.1	Both	0.28	0.11	0.26	0.12	0.28	0.48	
			1.5 years	0.25	0.11	0.22	0.09	0.23	0.44	
			4 years	0.32	0.10	0.30	0.18	0.31	0.49	<0.001
Mn	0.23	0	Both	12.41	3.98	12.41	6.75	11.89	20.29	
			1.5 years	13.48	4.08	12.83	8.28	12.73	21.20	
			4 years	11.34	3.57	10.67	5.59	11.06	17.28	<0.001

LOD limit of detection; AM arithmetic mean; SD standard deviation; GM geometric mean; perc percentile.
[1]p-values for differences between age groups (from Analysis of Variance [ANOVA] with natural log-transformed metal concentrations and with the factors age group, gender and region in the models).

performed by the Agency for Toxic Substances and Disease Registry (ATDSR), USA, a reference concentration of 1.4 µg Cd/L in whole blood was considered for Cd-related effects on the kidney in adults (Hays et al., 2008b). Although it may not be relevant to compare data from the present study on children with a reference concentration for adults, it can be concluded that the median Cd concentration in Riksmaten Young Children (0.10 µg/L) is more than ten times lower than the proposed reference concentration for kidney effects in adults. More recent studies have indicated effects of long-term Cd exposure on bone and the cardiovascular system in adults, the latter at blood Cd concentrations of 0.5 µg/L (Fagerberg and Barregard, 2021, Lamkarkach et al., 2021). The highest measured Cd concentration in Riksmaten Young Children was 0.5 µg/L.

The total concentration of **mercury (Hg)** in whole blood from 4-year-olds in the present study (median: 0.99 µg/L) was higher than in 4-year-olds in the NICE cohort (median: 0.6 µg/L,

estimated from concentrations in erythrocytes) (Vahter et al., 2024). The total Hg concentration in whole blood essentially reflects exposure to methylmercury from fish when the contribution from inorganic mercury is assumed to be small, which is assumed to be the case in today's Swedish children (Berglund et al., 2005, EFSA, 2012). Therefore, the difference in blood Hg concentrations between Riksmaten Young Children and NICE may indicate geographical differences in fish consumption (amount and/or type of fish) among Swedish children. There were only small differences between the overall blood Hg concentrations in 4-year-olds in Riksmaten Young Children (GM: 0.90 µg/L, AM: 1.12 µg/L) and school children in Lessebo (GM: 0.70 µg/L) (Mattisson et al., 2018), 5th graders in RMA (AM: 0.87 µg/L) (Livsmedelsverket & Naturvårdsverket, 2020) and 11-year-olds in Landskrona (GM: 1.3 µg/L) (Lundh et al., 2020). We could not find any Swedish Hg data on children around 1.5 years.

The German Human Biomonitoring Commission has derived Human Biomonitoring Assessment values (so called HBM I and HBM II values) for Hg and several other substances to provide guidance to interpret human biomonitoring data (Apel et al., 2017). According to their definition, a HBM I value represents the concentration of a substance in human biological material at or below there is no risk of adverse health effects and, consequently, no need for action, according to the current knowledge. A HBM II value is defined as the concentration of a substance in human biological material at or above which adverse health effects are possible and, consequently, an acute need for the reduction of exposure and the provision of biomedical advice is given. For levels between the HBM I value and the HBM II value adverse health effects cannot be excluded with sufficient certainty and a follow-up examination should be performed to determine whether there is a continued elevated exposure (Apel et al., 2017). Neurotoxicity is the critical effect of Hg, and HBM I and HBM II values of 5 and 15 µg/L, respectively, have been derived for both children and adults (Apel et al., 2017). In the present study, the 95th percentile of Hg was well below 5 µg/L (Table 4) and only one individual had a blood concentration above 5 µg/L (5.1 µg/L). The tolerable weekly intake (TWI) of methylmercury established by EFSA (1.3 µg/kg body weight, expressed as mercury) is based on a reference point of Hg in hair that was converted to a blood level of 46 µg/L (23 µg/L if an uncertainty factor of 2 is applied for the conversion from hair to blood) (EFSA, 2012). No participant in Riksmaten Young Children exceeded neither of these concentrations.

Lead (Pb) concentrations in 4-year-olds in the present study (GM: 6.5 µg/L, AM: 7.2 µg/L, median: 6.1 µg/L) were similar to those in 4-year-olds in the NICE cohort (median: 6.1 µg/L, estimated from concentrations in erythrocytes) (Vahter et al., 2024) and slightly lower compared with school children in Lessebo (GM: 9.9 µg/L) (Mattisson et al., 2018), 11-year-olds in Landskrona (GM: 7.8 µg/L) (Lundh et al., 2020) and 5th graders in RMA (AM: 8.4 µg/L) (Livsmedelsverket & Naturvårdsverket, 2020). We could not find any Swedish Pb data on children around 1.5 years. In EFSA's latest risk assessment of Pb, they established a reference point of 12 µg Pb/L blood for developmental neurotoxicity (loss in IQ) in small children (EFSA, 2010). In the present study, the 95th percentile of the measured Pb levels was 15.4 µg/L. Approximately 10% of the participants had Pb concentrations above 12 µg/L. This

is in line with previous findings in a study of school children in Landskrona, where 9% of the children sampled in 2022 exceeded 12 µg Pb/L blood (Stajnko et al., 2024) and in RMA where 13% of the adolescents exceeded 12 µg/L (Livsmedelsverket & Naturvårdsverket, 2020). Even though exposure to Pb has been reduced in the Swedish population including children since the 1970s (Lundh et al., 2020), the present findings demonstrate that exposure still is too high and underlines the importance of a further reduction from all sources.

The total **arsenic (As)** concentration in blood is a mixture of both organic arsenic compounds from fish and seafood (less toxic compounds like arsenobetain) and metabolites of inorganic arsenic (toxic). Chronic intake of inorganic As via diet and/or drinking water is associated with increased risk of cancers of the skin, bladder and lung (EFSA, 2024). The different fractions of organic and inorganic arsenic compounds are most often determined in urine, where the sum of metabolites of inorganic arsenic (methylarsonic acid, MMA, dimethylarsinic acid, DMA, and remaining unmethylated inorganic arsenic) reflects exposure to inorganic arsenic. Measurements of different arsenic compounds in urine from 4-year-old children in NICE cohort clearly indicated that most of the arsenic in urine consisted of the organic arsenic compound arsenobetain (Vahter et al., 2024). The median erythrocyte concentration of total arsenic in the NICE 4-year-olds was 1.4 µg/kg. Because erythrocytes contain higher concentrations of arsenic than plasma (Lu et al., 2015a), the mean concentrations of arsenic was higher in the children of Riksmaten Young Children (1.6 µg/L) than the NICE cohort. Most likely this is reflective of differences in seafood consumption, although it is possible that some children may also have been exposed to inorganic arsenic via drinking water or via high consumption of for example rice. In the present study, blood As concentrations among children in Umeå (northern Sweden) were lower than concentrations among children in Uppsala, Stockholm, Örebro, Gothenburg and Lund (Figure 4). We could not find any Swedish As data on children around 1.5 years. In addition, we could not find any human biomonitoring assessment value to compare our data with.

The median concentrations of **manganese (Mn)** in 4-year-olds in Riksmaten Young Children (11 µg/L, Table 4) was in line with that in 4-year-olds in NICE (median about 15 µg/L, estimated from concentrations in erythrocytes) (Vahter et al., 2024) and also similar to that in Swedish adolescents in RMA (median: 11 µg/L) (Livsmedelsverket & Naturvårdsverket, 2020). The median concentration of **cobalt (Co)** in 4-year-olds in Riksmaten Young Children (0.31 µg/L, Table 4) was higher than in RMA (median: 0.12 µg/L) (Livsmedelsverket & Naturvårdsverket, 2020). The median erythrocyte concentrations of Co in the 4-year-olds in NICE was 0.12 µg/kg (Vahter et al., 2024), but it is difficult to compare with whole-blood concentrations because the distribution between plasma, leucocytes and erythrocytes may vary. Mn is an essential trace element but may exhibit neurotoxicity at long-term elevated exposure (Kippler et al., 2024). Co is a component of vitamin B12, which is involved in cell metabolism and the production of red blood cells.

6.2.2 Age and gender differences

The 4-year-olds had significantly higher concentrations of Cd and Co in whole blood than the 1.5-year-olds (Table 4) while blood Mn concentrations were lower among the 4-year-olds compared with the 1.5-year-olds. For Cd, the age difference may be due to a more varied diet in the 4-year-olds with a larger proportion of foods that may contain Cd (e.g. cereals, potatoes, vegetables). The age differences for Co and Mn may also be due to differences in dietary patterns. (Livsmedelsverket, 2024)

There were no differences in blood concentrations of Cd, Hg, Pb or As between boys and girls in the present study. Boys had a significantly higher mean concentration of Co ($p=0.021$) and a lower mean concentration of Mn ($p=0.001$) than girls (data not shown). No significant gender differences in concentrations of Cd, Hg, Pb, As, Co or Mn were observed in 4-year-olds in the NICE cohort (Vahter et al., 2024).

6.2.3 Regional differences

Concentrations of metals in blood per region are presented in Figure 4. Although there were some significant differences between regions, they were generally small and not consistent. For example, the levels of Cd were slightly higher in Lund than in the other regions and lower in Umeå compared with Stockholm, Gothenburg and Lund. Furthermore, concentrations of Hg were higher in Stockholm and Örebro compared with Uppsala and the concentrations of As were lower in Umeå than in Uppsala, Stockholm, Örebro, Gothenburg and Lund (Figure 4). The reasons for the observed differences are unknown, but may be explained by differences in food consumption, drinking water levels, industrial emissions, or by chance. There were no differences in blood Pb concentrations between regions. In RMA, there were no differences in blood concentrations of Cd, Hg, Pb, Co or Mn in samples from adolescents living in different regions of Sweden (As was not analysed) (Livsmedelsverket & Naturvårdsverket, 2020).

6.2.4 Conclusions

Cd, Hg, Pb, As, Co and Mn were found in concentrations above LOD in almost all whole blood samples from Riksmaten Young Children and in concentrations that were generally expected. 4-year-olds had higher blood concentrations of Cd than 1.5-year-olds. There were small and non-consistent differences in metal concentrations between geographical regions. Comparisons with human biomonitoring assessment values showed that, based on current knowledge, the exposure to Hg in children is not a health concern. There is currently no assessment value for Cd in children to compare our data with, but the observed blood concentrations were within the expected range. For Pb, 10% of the participants had blood concentrations above EFSA's reference point for developmental neurotoxicity in small children. Similar results have been obtained in other studies of Swedish children. This underlines the importance of further reducing lead exposure from all sources, not only food.

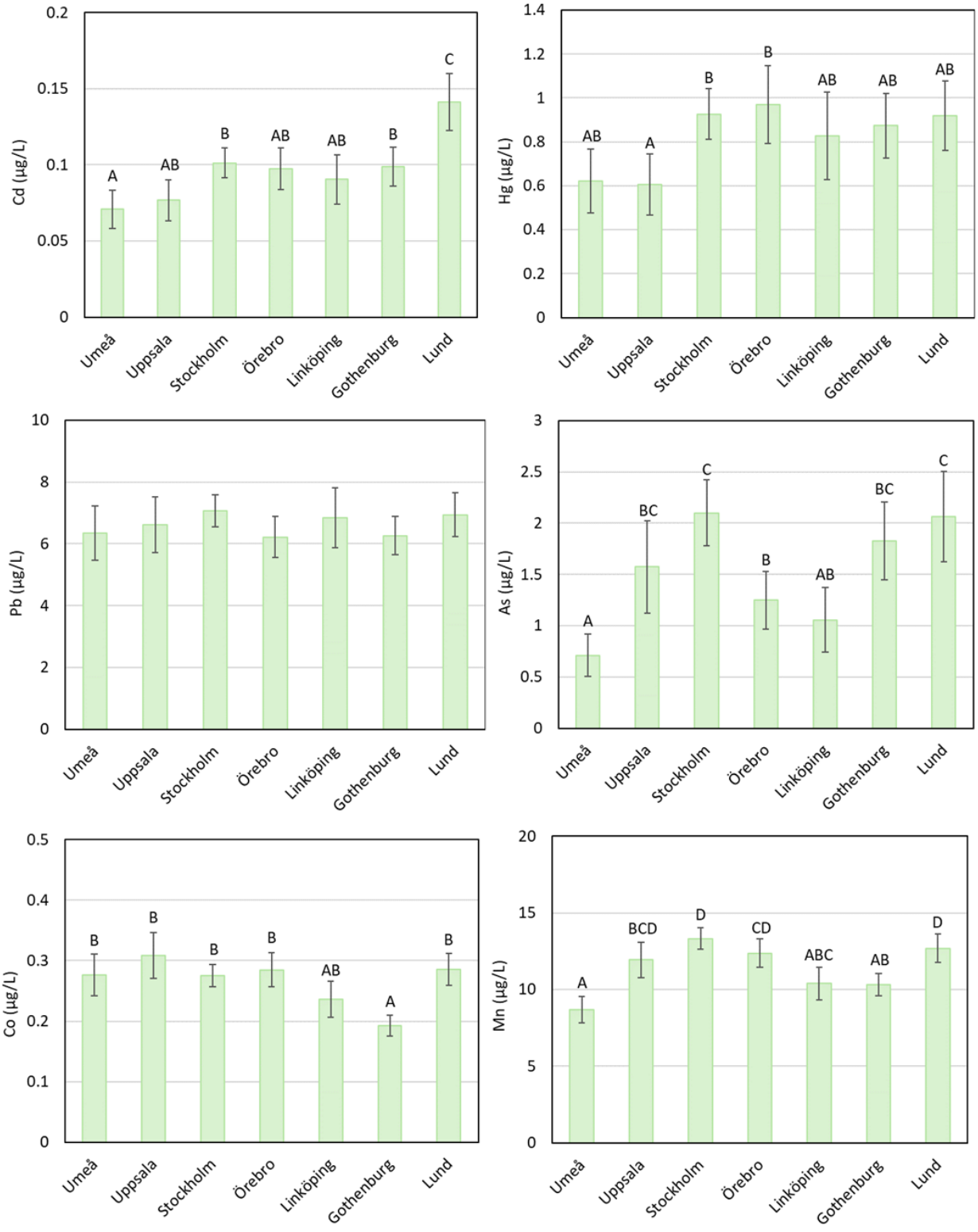

Figure 4. Concentrations of metals (µg/L) in whole blood in Swedish 1.5- and 4-year-olds (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region, age group and gender). Different letters above the bars indicate significant differences between regions ($p<0.05$) according to Tukey's multiple comparison test. Number of observations per region: Umeå N=45, Uppsala N=46, Stockholm N=159, Örebro N=75, Linköping N=43, Gothenburg N=88, Lund N=82.

6.3 Per- and polyfluoroalkyl substances in serum

6.3.1 Concentrations and comparisons with human biomonitoring assessment values

PFAS comprise a large group of chemicals that have been used in a variety of fields due to their water- and grease repellent properties, for example in textiles, kitchenware, fire-fighting foam and medical equipment. PFAS are considered environmentally persistent, and humans are mainly exposed via food and drinking water. Studies have shown that PFAS exposure may for example affect birth weight, antibody response after vaccination, serum levels of cholesterol and liver enzymes. (EFSA, 2020)

The number of serum samples available for analysis of PFAS was 559 (1.5-year-olds N=287, 4-year-olds N=272). Concentrations of single PFAS and the sum of PFOA, PFNA, PFHxS and tot-PFOS (ΣPFAS4) are presented in Table 5. PFPeA, PFHxA, PFDoDA, PFTrDA and PFDS were included in the analytical method, but the signals for these compounds were too low to be quantified. The highest mean concentrations were found for PFOS followed by PFOA and PFHxS. About two thirds of the total amount of PFOS (tot-PFOS) consisted of the linear form (lin-PFOS) and one third of the branched (br-PFOS).

The mean concentrations of PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFHxS and PFOS were considerably lower in 4-year-olds in Riksmaten Young Children than in 4-year-olds sampled in Uppsala in 2020-2022 (N=19) (Lindfeldt et al., 2023). The largest difference was observed for PFHxS, where the median in the Uppsala children was 2.4 ng/g serum (corresponding to ca 2.4 ng/mL) compared with a median of 0.6 ng/mL in all 4-year-olds in the present study (Table 5). However, the 4-year-olds in Uppsala are not representative of the Swedish general population of 4-year-olds since Uppsala city has a history of contaminated drinking water, especially with PFHxS (Gyllenhammar et al., 2019). We could not find any other Swedish studies of PFAS in 1.5-year-olds, but Hagberg et al. (2024) analysed PFAS in serum from ten infants born in Örebro in 2014-2017 when they were 3, 6 and 12 months of age. At 12 months of age, the Örebro infants had serum concentrations of PFHpA (AM: 0.18 ng/mL), PFHxS (AM: 1.1 ng/mL) and PFHpS (AM: 0.14 ng/mL) similar to those that we found in 1.5-years-old in the present study, while the concentrations of PFOA (AM: 3.8 ng/mL), PFNA (AM: 1.2 ng/mL) and tot-PFOS (AM: 6.1 ng/mL) were higher in the Örebro infants.

A comparison of the present study with PFAS results from adolescents participating in RMA in 2016-17 (Livsmedelsverket & Naturvårdsverket, 2020) shows that the mean concentrations of PFHpA, PFOA, PFNA and PFDA in adolescents (AM: 0.09, 1.4, 0.4 and 0.2 ng/g, respectively) were similar or somewhat lower than in Riksmaten Young Children, while the concentrations of PFHxS (AM: 1.8 ng/g) and tot-PFOS (AM: 4.6 ng/g) were higher in adolescents.

Table 5. Concentrations of PFAS (ng/mL) in blood serum in Swedish 1.5-year-olds (N=287) and 4-year-olds (N=272) participating in Riksmaten Young Children. Concentrations below LOD were replaced by LOD/√2 in the calculations.

Substance	LOD	% of samples <LOD	Age group	AM	SD	GM	5th perc	Median	95th perc	p[1]
PFBA	0.05	4.8	Both	0.13	0.12	0.10	0.05	0.10	0.30	
			1.5 yrs	0.16	0.11	0.14	0.06	0.13	0.38	
			4 yrs	0.09	0.11	0.08	<LOD	0.07	0.17	<0.001
PFHpA	0.01	0	Both	0.18	0.14	0.14	0.05	0.14	0.45	
			1.5 yrs	0.24	0.15	0.20	0.08	0.21	0.56	
			4 yrs	0.11	0.07	0.10	0.04	0.10	0.24	<0.001
PFOA	0.01	0	Both	1.78	1.26	1.49	0.57	1.49	4.15	
			1.5 yrs	2.18	1.49	1.79	0.57	1.87	5.18	
			4 yrs	1.37	0.76	1.23	0.61	1.18	2.57	<0.001
PFNA	0.02	0	Both	0.51	0.62	0.42	0.17	0.42	1.1	
			1.5 yrs	0.61	0.83	0.47	0.16	0.47	1.4	
			4 yrs	0.41	0.19	0.38	0.18	0.38	0.70	<0.001
PFDA	0.04	0.2	Both	0.19	0.10	0.17	0.08	0.17	0.37	
			1.5 yrs	0.20	0.11	0.17	0.08	0.17	0.39	
			4 yrs	0.18	0.07	0.17	0.09	0.17	0.31	0.721
PFUnDA	0.07	40	Both	0.10	0.07	0.08	<LOD	0.08	0.22	
			1.5 yrs	0.09	0.08	0.07	<LOD	<LOD	0.22	
			4 yrs	0.11	0.06	0.10	<LOD	0.10	0.21	<0.001
PFBS	0.01	6.4	Both	0.03	0.03	0.03	<LOD	0.03	0.08	
			1.5 yrs	0.04	0.03	0.04	0.02	0.04	0.10	
			4 yrs	0.02	0.02	0.02	<LOD	0.02	0.06	<0.001
PFPeS	0.05	68	Both	0.06	0.04	0.05	<LOD	<LOD	0.13	
			1.5 yrs	0.06	0.05	0.05	<LOD	<LOD	0.16	
			4 yrs	0.05	0.04	0.04	<LOD	<LOD	0.11	<0.001
PFHxS	0.03	0	Both	0.94	1.07	0.67	0.20	0.65	2.81	
			1.5 yrs	1.10	1.20	0.76	0.20	0.72	3.25	
			4 yrs	0.79	0.90	0.59	0.20	0.57	2.05	<0.001
PFHpS	0.02	3.2	Both	0.08	0.06	0.07	0.02	0.07	0.18	
			1.5 yrs	0.09	0.07	0.07	<LOD	0.08	0.23	
			4 yrs	0.07	0.04	0.07	0.03	0.07	0.13	0.007
tot-PFOS	0.05	0	Both	2.93	1.83	2.52	1.08	2.49	6.01	
			1.5 yrs	3.15	2.17	2.60	0.93	2.69	7.06	
			4 yrs	2.71	1.35	2.45	1.29	2.38	5.04	0.090
lin-PFOS	0.05	0	Both	1.96	1.37	1.61	0.58	1.64	4.40	
			1.5 yrs	2.07	1.62	1.62	0.50	1.71	5.08	

Substance	LOD	% of samples <LOD	Age group	AM	SD	GM	5th perc	Median	95th perc	p[1]
			4 yrs	1.83	1.02	1.61	0.80	1.58	3.69	0.686
br-PFOS	0.05	0	Both	0.93	0.51	0.83	0.40	0.82	1.77	
			1.5 yrs	1.04	0.60	0.91	0.39	0.91	2.00	
			4 yrs	0.82	0.35	0.76	0.41	0.74	1.37	<0.001
ΣPFAS4[2]	-	-	Both	6.18	3.86	5.32	2.20	5.30	13.3	
			1.5 yrs	7.03	4.71	5.82	1.93	5.75	15.8	
			4 yrs	5.28	2.40	4.84	2.47	4.74	9.19	<0.001

LOD limit of detection; AM arithmetic mean; SD standard deviation; GM geometric mean; perc percentile.
[1]p-values for differences between age groups (from Analysis of Variance [ANOVA] with natural log-transformed concentrations and with the factors age group, gender and region in the models).
[2]sum of PFOA, PFNA, PFHxS and tot-PFOS.

In the latest risk assessment performed by EFSA, a TWI for ΣPFAS4 was derived based on an inverse association between serum levels of ΣPFAS4 and antibody titres against diphtheria in 1-year-old children (EFSA, 2020). EFSA estimated that there is no risk of adverse effects at serum levels of ΣPFAS4 up to 17.5 ng/mL in 1-year-old children, and they used this level as starting point for the modelling of a TWI. In the present study, 13 1.5-year-olds (4.5%) had concentrations of ΣPFAS4 above 17.5 ng/mL. The highest measured ΣPFAS4 concentration was 31.8 ng/mL. These results show that some of the children have had a PFAS exposure during the foetal stage and first years of life that is higher than desirable. In turn, this indicates that some of the mothers of the children have had elevated PFAS exposures during their lifetime as PFAS is transferred to children during pregnancy and breast-feeding. The levels of several PFAS in human samples and in food on the Swedish market have decreased since about 2000 (Gyllenhammar et al., 2023b, Livsmedelsverket, 2024), but the results from the present study underline the importance of further reducing PFAS exposure in the Swedish population. Only one of the 4-year-olds had a ΣPFAS4 concentration above 17.5 ng/mL, and the higher prevalence of high ΣPFAS4 concentrations among 1.5-year-olds indicates that exposure during pregnancy and breast-feeding are important contributors to the exposure in young children. This is also supported by the higher mean levels of ΣPFAS4 in 1.5-year-olds than in 4-year-olds (see section 6.3.2). However, PFAS exposure of the children from drinking water and food during their first years of life has also contributed to the concentrations found in serum.

6.3.2 Age and gender differences

The mean concentration of all PFAS except for PFUnDA was higher in 1.5-year-olds than in 4-year-olds. The age differences were significant for PFBA, PFHpA, PFOA, PFNA, PFBS, PFPeS, PFHxS, PFHpS, br-PFOS and ΣPFOS4 (Table 5). Similar results were obtained in a Finnish study where serum levels of PFOA, PFNA, PFOS and PFHxS decreased between 1 and 6 years of age among 54 children who were repeatedly sampled (Koponen et al., 2018). The

reason for the decrease is probably that serum concentrations of PFAS increases during the first months of life due to a high exposure from breastmilk, and thereafter decreases when the breast-feeding period is over and the exposure from food is lower (EFSA, 2020, Koponen et al., 2018).

Except for a slightly higher adjusted mean concentration of PFBS in boys (0.031 ng/mL) than in girls (0.028 ng/mL) ($p=0.035$), there were no significant differences in mean concentrations of PFAS between boys and girls (results not shown). In studies of adolescents and adults, for example in RMA and Riksmaten adults 2010-11, the levels of several PFAS were higher in men than in women (Bjermo et al., 2013, Livsmedelsverket & Naturvårdsverket, 2020). The lack of gender differences in the present study is expected because it is generally assumed that menstruation, pregnancy and lactation is responsible for gender differences. In a US study, it was observed that women began to have lower serum levels of PFAS than men around the age of 11-15 years (Jain and Ducatman, 2022).

6.3.3 Regional differences

PFAS concentrations in serum per region are presented in Figure 5 and Figure 6. There were generally small differences in levels of PFCAs between regions, but the concentrations were consistently higher in Stockholm than in Umeå (Figure 5). Among the PFSAs, concentrations of PFBS, PFPeS, PFHxS and PFHpS were highest in children from Uppsala and Stockholm, and for PFPeS and PFHxS they were also higher in Uppsala than in Stockholm (Figure 6). There were only minor regional differences in PFOS levels. Altogether, ΣPFAS4 was highest in Uppsala followed by Stockholm and Linköping and lowest in Umeå (Figure 6).

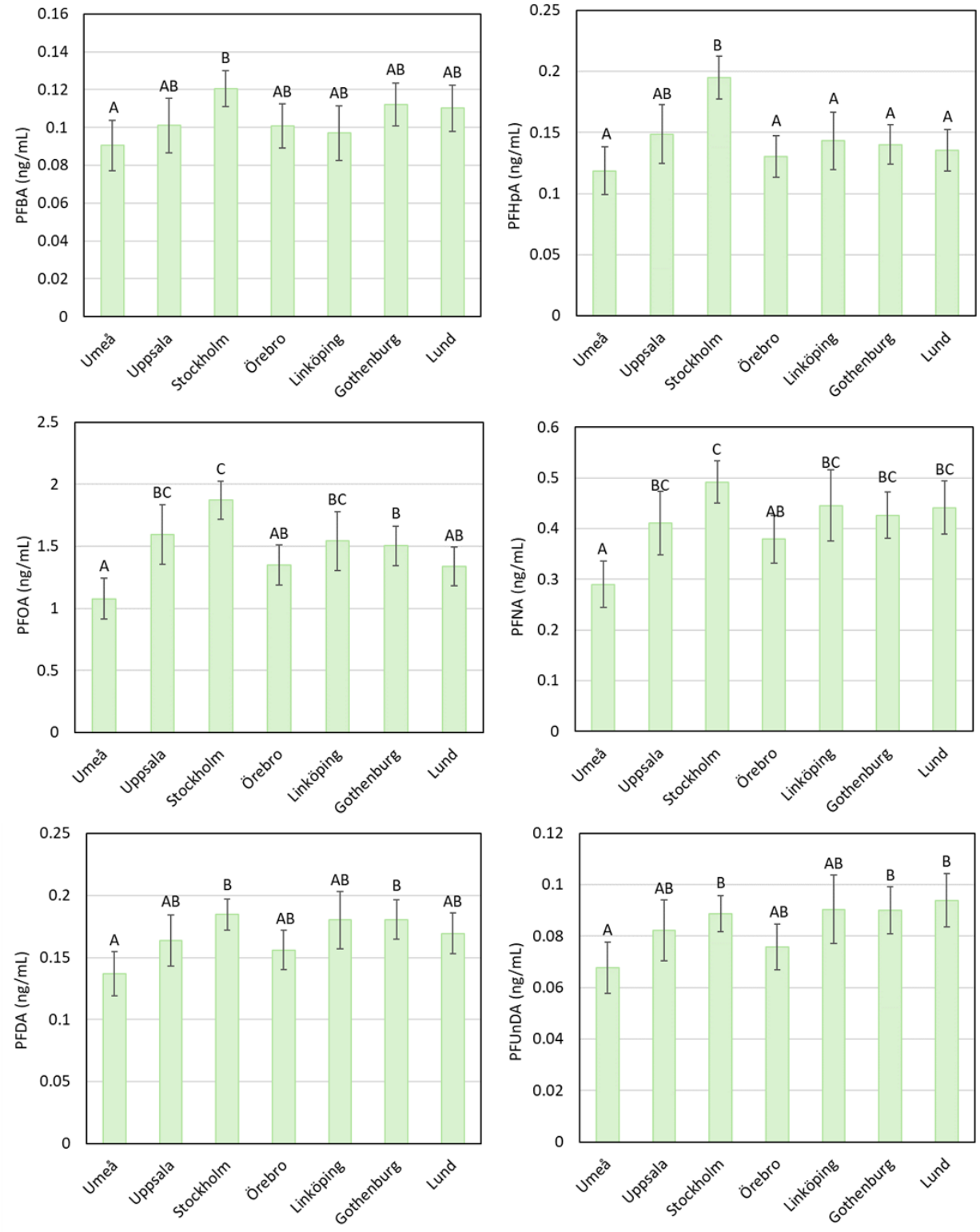

Figure 5. Concentrations of perfluoroalkyl carboxylic acids (ng/mL) in serum in Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region, age group and gender). Different letters above the bars indicate significant differences between regions ($p<0.05$) according to Tukey's multiple comparison test. Number of observations per region: Umeå N=46, Uppsala N=49, Stockholm N=162, Örebro N=75, Linköping N=47, Gothenburg N=98, Lund N=82.

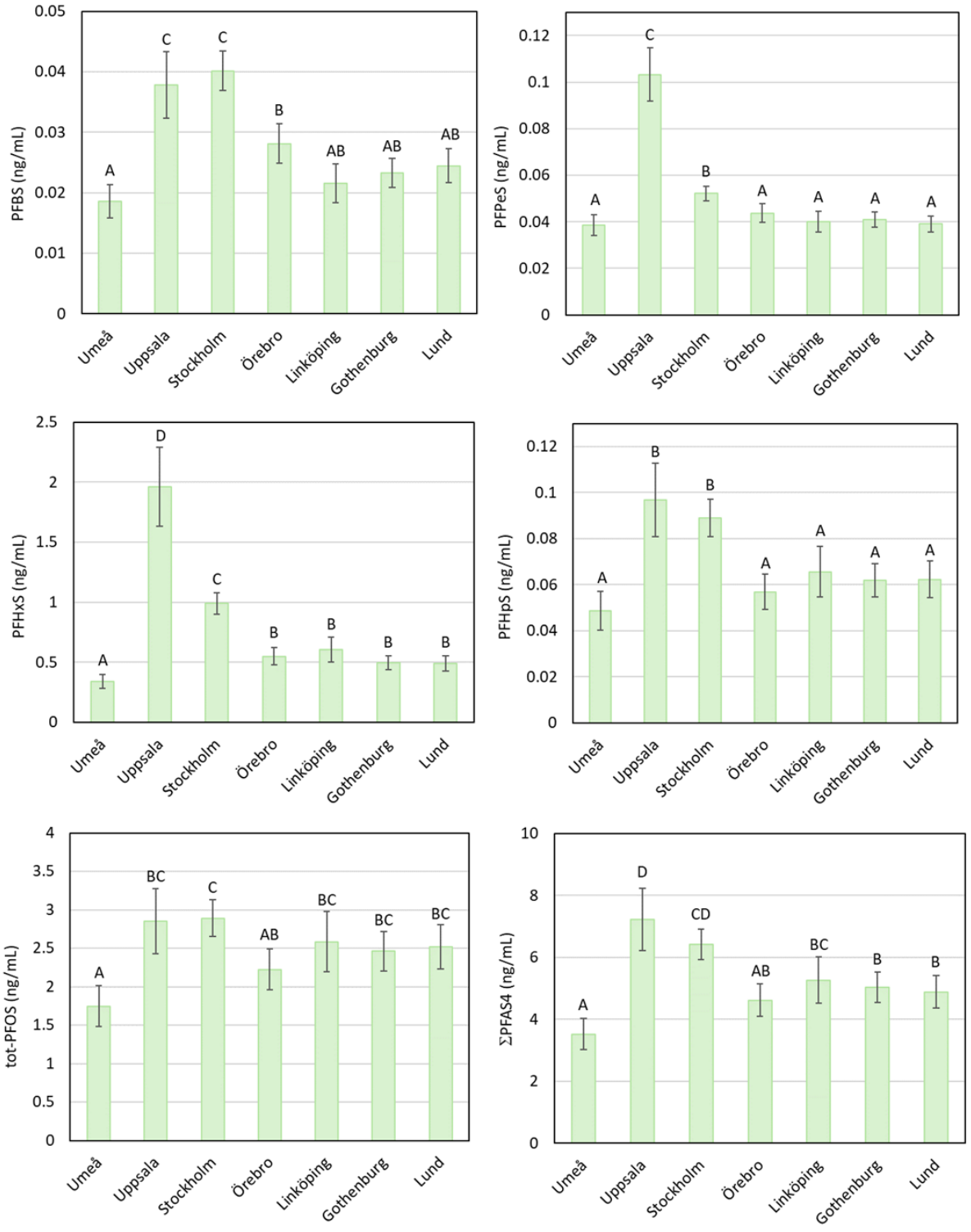

Figure 6. Concentrations of perfluoroalkyl sulfonic acids and ΣPFAS4 (sum of PFOA, PFNA, PFHxS and tot-PFOS) in serum in Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region, age group and gender). Different letters above the bars indicate significant differences between regions ($p<0.05$) according to Tukey's multiple comparison test. Number of observations per region: Umeå N=46, Uppsala N=49, Stockholm N=162, Örebro N=75, Linköping N=47, Gothenburg N=98, Lund N=82.

A reason for the generally higher PFAS exposure in Uppsala and Stockholm is probably a higher degree of contamination of drinking water in these areas. Drinking water in the city of Uppsala has historically been contaminated with PFAS, especially PFHxS, PFOS, PFBS, PFHxA and PFOA (Gyllenhammar et al., 2015). Even though measures to reduce PFAS levels in drinking water were introduced already in 2012 (Gyllenhammar et al., 2015), they continued to be elevated in later analyses (Livsmedelsverket, 2021). Certain areas of Stockholm also have a history of elevated PFAS levels in drinking water (Livsmedelsverket, 2021). Elevated drinking water levels have probably resulted in higher body burdens in women living in these areas and consequently a higher transfer to the children during pregnancy and breastfeeding. Additionally, PFAS exposure of the children from drinking water during their first years of life also contributed to the concentrations found in serum.

6.3.4 Conclusions

Among the analysed PFAS, highest concentrations were found of PFOS, PFOA and PFHxS among the participants in Riksmaten Young Children. There is a lack of other Swedish studies in children to compare these results with. There were no relevant differences in PFAS levels between boys and girls, but 1.5-year-olds had higher concentrations of almost all analysed PFAS than 4-year-olds, probably due to a relatively higher exposure during the foetal and breastfeeding periods than later. The levels of PFBS, PFPeS, PFHxS, PFHpS and ΣPFAS4 were highest in samples from children in Uppsala and Stockholm. The reason for higher levels in certain regions is probably a history of elevated PFAS-concentrations in drinking water in these areas.

Of the 1.5-year-olds in Riksmaten Young Children, 4.5% had concentrations of ΣPFAS4 above the health-based reference point in 1-year-old children that EFSA used as starting point for deriving a TWI. This indicates that some of the children in Riksmaten Young Children had PFAS exposures during the foetal stage and early life that were higher than desirable. The levels of several PFAS in human samples and in food on the Swedish market have decreased since about 2000 (Gyllenhammar et al., 2023b, Livsmedelsverket, 2024), and the results in the present study underline the importance of further reducing PFAS exposure in the Swedish population. In January 2026, a new national maximum limit for ΣPFAS4 in drinking water will be implemented. The new maximum limit is considerably lower than the previously applicable action limit for PFAS in drinking water and will probably lead to reduced exposure.

6.4 4-hydroxy-chlorothalonil in serum

4-hydroxychlorothalonil (HCT) is a transformation product of chlorothalonil, a fungicide that has been used on e.g. fruits and vegetables, as paint additive and as wood preservative since the 1960s. Chlorothalonil was banned for use in agriculture within the European Union in 2019 (European Commission, 2019). The International Agency for Research on Cancer (IARC) has classified chlorothalonil as possibly carcinogenic to humans based on results from animal studies (IARC, 1999). There is a lack of toxicity data for HCT, but a genotoxic potential cannot be excluded (EFSA, 2018). In addition, HCT and several other metabolites have been shown to have a high persistence in the environment (EFSA, 2018). HCT has recently been identified in serum from pregnant women in Sweden and Costa Rica (Krais et al., 2024) and in breast milk from women in Costa Rica (Runkel et al., under preparation). Chlorothalonil is still widely used in agriculture in Central America, and serum concentrations of HCT are hence higher in Costa Rica than in Sweden (Krais et al., 2024).

In the present study, the number of serum samples available for analysis of HCT was 559 (1.5-year-olds: N=287, 4-year-olds: N=272). HCT was detected in all samples and the mean concentration was about two times higher in 1.5-year-olds than in 4-year-olds (Table 6). There were no differences in mean concentrations between boys and girls or between regions (results not shown). Human data on HCT are very limited, but the median concentration in the present study (1.8 ng/mL) was lower than in Swedish pregnant women (N=1808) sampled in 1997-2015 (median: 4.1 ng/mL) (Krais et al., 2024). There is no human biomonitoring assessment value for HCT to compare our data with.

Table 6. Concentrations of HCT (4-hydroxy-chlorothalonil) (ng/mL) in blood serum in Swedish 1.5- and 4-year-olds (N=559, whereof 287 1.5-year-olds and 272 4-year-olds) participating in Riksmaten Young Children.

Substance	LOD	% of samples <LOD	Age group	AM	SD	GM	5th perc	Median	95th perc	p[1]
HCT	0.06	0	Both	2.71	2.89	1.96	0.62	1.76	7.96	
			1.5 years	3.73	3.58	2.69	0.74	2.55	11.0	
			4 years	1.63	1.22	1.96	0.60	1.41	3.33	<0.001

LOD limit of detection; AM arithmetic mean; SD standard deviation; perc percentile.
[1]p-values for differences between age groups (from Analysis of Variance [ANOVA] with natural log-transformed concentrations and with age group, gender and region in the models).

Our results indicate that Swedish children are exposed to chlorothalonil or its transformation products despite the discontinued use in agriculture in Sweden since 1991 and the ban of chlorothalonil in agriculture within the European Union in 2019 (European Commission, 2019). Chlorothalonil is however still widely used in Central America in for example banana plantations and is also allowed for different applications in e.g. Southeast Asia and the United States (Krais et al., 2024). Krais et al. (2024) suggests that different sources, e.g. paints, contaminated food and drinking water and atmospheric long-range transport, might be

responsible for the exposure of the general Swedish population. They also showed that serum levels of HCT in pregnant women decreases with increasing parity, which indicates that HCT is transferred from mother to child during pregnancy and breastfeeding (Krais et al., 2024). The results from Riksmaten Young Children strengthens this hypothesis and the observed lower levels in 4-year-olds compared with 1.5-year-olds suggest that exposure during the foetal and breastfeeding periods is higher than later exposure from other sources.

6.5 Organic contaminants in urine

6.5.1 Concentrations and comparisons with human biomonitoring assessment values

The number of urine samples available for analysis was 334 (1.5-year-olds N=61, 4-year-olds N=273). Concentrations of phthalate metabolites and DiNCH metabolites are presented in Table 7 and concentrations of the other organic contaminants in Table 8. The analysed substances are short-lived and rapidly excreted from the body via urine. Thus, measured concentrations are an indicator of recent exposure. Due to large matrix effects and interferences affecting some substances, these could not be determined in all samples. Some of the urine samples were sampled from potties, and this may have contributed to the matrix effects. Information about sampling method (i.e. via potty or not) for each individual sample is however not available.

Metabolites of phthalates and DINCH

Phthalates (diesters of phthalic acid) are used as plasticizers, solvents and additives in many industrial, personal care and medical device products (Gkrillas et al., 2021). Common exposure routes are via food and beverages, due to release of phthalates from food packaging materials, and indoor environments (e.g. dust and air) (Sjostrom et al., 2023, Gkrillas et al., 2021). Several phthalates are classified as endocrine disruptors and toxic to reproduction. Due to the toxicity, some phthalates have been regulated and subsequently replaced by e.g. DiNCH (Gkrillas et al., 2021, EFSA, 2019a).

All the analysed metabolites of phthalates and DiNCH could be detected in most samples (>99%). MnBP showed the highest concentrations of the phthalate metabolites, followed by MEP and MiBP (Table 7). Of the two DiNCH metabolites, OH-MiNCH was detected in highest concentrations. The concentrations of phthalate metabolites and DiNCH metabolites in Riksmaten Young Children were generally lower or similar than in Swedish pre-school children (mean age of 5 years) recruited in Eskilstuna and Vingåker in 2016 (Sjostrom et al., 2023) and 4-year-olds in Stockholm sampled between 2019 and 2022 (Lindh et al., 2022) (Appendix 2, Table A2:1). In comparison with the previous Riksmaten survey conducted in adolescents in 2016-2017 (RMA), the concentrations were over-all similar (Livsmedelsverket & Naturvårdsverket, 2020). However, the median sum of MnBP and MiBP was higher in young children (54 ng/mL) than in adolescents (40 ng/mL). On the contrary, MEP, a metabolite of DEP, was about twice as high in adolescents (33 ng/mL) compared with young

children in the present (14 ng/mL) and another Swedish study (16 ng/mL (Sjostrom et al., 2023)). This indicates that there may be an age difference in exposure to DEP and urinary MEP has previously been associated with exposure from personal care products rather than food (Gkrillas et al., 2021). To our knowledge, MnHxP has not been analysed in Swedish urine samples earlier, but the presence of this metabolite in urine has been noted in Germany (LANUV, 2024, Pirow et al., 2024). The concentrations of MnHxP in 2- to 6-year-old children in Germany (mean 2.1 ng/mL, median 0.56 ng/mL) (LANUV, 2024) were slightly lower than in Riksmaten Young Children (mean 2.5 ng/mL, median 1.1 ng/mL).

The German Human Biomonitoring Commission has derived HBM I values for phthalate metabolites and DiNCH metabolites that the concentrations in Riksmaten Young Children can be compared with. A HBM I value represents the concentration of a substance in human biological material at or below, according to the current knowledge, there is no risk of adverse health effects and, consequently, no need for action (Apel et al., 2017). There are HBM I values for metabolites of DEHP (sum of 5-oxo- and 5-OH-MEHP), DPHP (OH-MPHP), DnBP (MnBP), DiBP (MiBP), BBzP (MBzP) and DiNCH (OH-MiNCH and cx-MiNCH) (Lange et al., 2021). The critical effects were reproductive and developmental toxicity for DEHP, DnBP, BBzP and DiBP, thyroid toxicity for DPHP, and kidney toxicity for DiNCH. It should be noted that these HBM I values were derived for children 6-13 years of age, and no values are available for younger children due to lack of relevant toxicokinetic data (Lange et al., 2021).

All children in the present study had concentrations far below the HBM I values for the metabolites of DEHP (340 ng/mL), DPHP (140 ng/mL) and BBzP (2000 ng/mL) (Lange et al., 2021). The highest concentrations of these metabolites were 183 ng/mL, 32 ng/mL, and 375 ng/mL, respectively. The 95th percentiles of the metabolites of DnBP and DiBP were also below their HBM I values (120 ng/mL and 160 ng/mL, respectively (Lange et al., 2021)), except for DnBP in 1.5-year-olds with a 95th percentiles of 161 ng/mL. Among all children in Riksmaten Young Children, 14 (4%) and 6 (1%) children had urine concentrations above the HBM I values for DnBP and DiBP metabolites, respectively. The results from the present study thus show that a continued biomonitoring of DnBP and DiBP is relevant despite that the use of these substances is regulated within the EU (EFSA, 2019a). Urine concentrations of several phthalate metabolites are decreasing (Lindh et al., 2022, Gyllenhammar et al., 2023a), but MnBP and MiBP were not included in these trend analyses. Notably, the concentrations of the sum of MnBP and MiBP are similar in Riksmaten Young Children as in children sampled in 2016 (Sjostrom et al., 2023); mean and medians were 69 ng/mL and 51 ng/mL in the 4-year-olds of Riksmaten Young Children, and 69 ng/mL and 55 ng/mL in the urine collected in 2016.

For DiNCH, the HBM I value is based on the sum of the metabolites OH-MiNCH and cx-MiNCH. The highest concentration detected in Riksmaten Young Children was 339 ng/mL, and no children had concentrations above the HBM I value of 3000 ng/mL (Lange et al., 2021).

Table 7. Density-adjusted concentrations of metabolites of phthalates and DiNCH (ng/mL) in urine from Swedish 1.5- and 4-year-olds (N=334, whereof 61 1.5-year-olds and 273 4-year-olds) participating in Riksmaten Young Children. Concentrations below LOD were replaced by LOD/√2 in the calculations.

Substance	LOD	% of samples <LOD	Age group	N[1]	AM	SD	GM	5th perc	Median	95th perc	p[2]
Phthalate metabolites											
MEP	0.1	0	Both	334	34.3	113	15.2	3.50	14.1	98.5	
			1.5 yrs	61	19.6	17.5	14.3	3.71	14.3	57.5	
			4 yrs	273	37.5	124	15.4	3.35	14.0	128	0.649
MBzP	0.06	0	Both	334	13.4	33.2	5.61	1.19	4.75	46.7	
			1.5 yrs	61	25.5	64.4	7.33	1.23	5.66	115	
			4 yrs	273	10.7	19.8	5.28	1.16	4.71	41.2	0.024
MnBP	0.4	0	Both	334	45.2	60.2	31.5	9.07	31.2	108	
			1.5 yrs	61	59.7	88.1	40.2	11.9	41.3	161	
			4 yrs	273	42.0	51.7	29.8	8.94	28.5	101	0.006
MiBP	0.6	0	Both	334	29.1	44.0	19.4	6.65	18.3	92.4	
			1.5 yrs	61	38.9	75.0	21.8	7.36	18.9	132	
			4 yrs	273	27.0	33.1	18.9	6.61	18.1	75.1	0.232
MnHxP	0.08	1	Both	334	2.48	4.42	1.15	0.22	1.05	11.5	
			1.5 yrs	61	2.72	4.79	1.26	0.30	1.23	9.72	
			4 yrs	273	2.43	4.34	1.13	0.21	1.03	11.5	0.582
5-oxo-MEHP	0.03	0	Both	333	5.99	8.37	4.11	1.22	3.90	15.1	
			1.5 yrs	61	7.43	10.3	4.78	1.46	4.00	16.7	
			4 yrs	272	5.67	7.87	3.97	1.22	3.85	14.0	0.137
5-OH-MEHP	0.06	0	Both	331	9.00	10.2	6.31	1.70	6.28	26.0	
			1.5 yrs	60	8.78	10.7	5.77	1.54	5.68	29.4	
			4 yrs	271	9.05	10.1	6.43	1.77	6.36	25.3	0.305
5-cx-MEPP	0.03	0	Both	331	12.2	12.9	8.85	2.99	7.99	34.4	
			1.5 yrs	61	13.9	14.3	9.73	3.40	8.94	35.9	
			4 yrs	270	11.8	12.6	8.67	2.93	7.81	32.2	0.380
oxo-MiNP	0.03	0	Both	332	3.33	3.75	2.25	0.60	2.08	12.2	
			1.5 yrs	61	3.72	4.18	2.31	0.69	1.94	14.0	
			4 yrs	271	3.24	3.65	2.24	0.56	2.10	10.0	0.965
OH-MiNP	0.04	0	Both	323	3.68	2.96	2.82	0.86	2.90	8.90	
			1.5 yrs	57	3.28	2.20	2.54	0.53	2.70	7.03	
			4 yrs	266	3.77	3.09	2.88	0.87	2.94	9.10	0.384
cx-MiNP	0.06	0	Both	331	9.66	14.7	6.23	1.66	5.70	28.0	
			1.5 yrs	61	8.96	8.11	6.22	1.55	5.20	27.9	
			4 yrs	270	9.82	15.8	6.23	1.67	5.89	28.2	0.938

Substance	LOD	% of samples <LOD	Age group	N[1]	AM	SD	GM	5th perc	Median	95th perc	p[2]
cx-MiDP	0.2	0.3	Both	333	1.78	3.29	1.21	0.46	1.12	4.50	
			1.5 yrs	61	2.59	6.03	1.49	0.55	1.25	5.68	
			4 yrs	272	1.60	2.24	1.16	0.46	1.07	4.03	0.013
OH-MPHP	0.04	0.3	Both	332	0.85	2.08	0.49	0.15	0.47	2.28	
			1.5 yrs	61	0.78	0.66	0.58	0.20	0.53	2.02	
			4 yrs	271	0.86	2.28	0.47	0.15	0.45	2.28	0.099
DiNCH metabolites											
cx-MiNCH	0.03	0	Both	329	3.10	8.53	1.57	0.41	1.40	9.86	
			1.5 yrs	61	4.74	15.5	1.77	0.32	1.73	9.95	
			4 yrs	268	2.72	5.88	1.52	0.44	1.36	9.00	0.184
OH-MiNCH	0.03	0	Both	334	7.27	18.3	3.58	1.05	3.05	24.5	
			1.5 yrs	61	10.1	29.5	4.34	1.35	4.15	24.5	
			4 yrs	273	6.63	14.6	3.43	1.02	2.96	21.7	0.051

LOD limit of detection; AM arithmetic mean; SD standard deviation; GM geometric mean; perc percentile; abbreviations of compounds are referred to table 2.

[1]Due to large matrix effects, some substances could not be determined in all samples and N-values consequently differ between substances.

[2]p-values for differences between age groups (from Analysis of Variance [ANOVA] with natural log-transformed concentrations and with the factors age group, gender and region in the models).

Organophosphate flame retardant metabolites

Organophosphate flame retardants have to some extent replaced polybrominated diphenyl ethers (PBDEs) when those were banned due to their persistence, bioaccumulation and adverse health effects. They are widely used as flame retardants in for example electronics, textiles, furniture, and industrial materials but also as plasticizers in polyvinyl chloride. Food intake is an important exposure source for organophosphate flame retardants although humans can also be exposed through inhalation of air, dust, and dermal uptake (Gbadamosi et al., 2022, Poma et al., 2017). The main route of exposure for toddlers seems to be dust ingestion (Rodriguez Martin et al., 2023). Data on toxicity is insufficient, but organophosphate flame retardants have potential for endocrine disruption and have been suggested to cause for example neurotoxicity and developmental toxicity (Yao et al., 2021).

DPP (metabolite of TPP) and BDCIPP (metabolite of TDCIPP) could be detected in most samples (100% and 91%, respectively), whereas BBOEP (metabolite of TBOEP) was above the detection limit in 60% of the samples. LOD was however higher for BDCIPP (0.1 ng/mL) than the other two metabolites (0.03 ng/mL). DPP was also present at the highest concentrations (Table 8). The measured concentrations were in line with those in 4-year-olds in Stockholm between 2019 and 2022 (Lindh et al., 2022), but slightly lower than those observed in adolescents in RMA (Livsmedelsverket & Naturvårdsverket, 2020) (Appendix 2,

Table A2:2). We could not find any human biomonitoring assessment values for DPP, BDCIPP or BBOEP to compare our data with.

Bisphenols

Bisphenol A (BPA) is used in e.g. production of polycarbonate and epoxy plastics used for manufacturing food and liquid containers (EFSA, 2023). It can migrate to food from the material. Intake from food is therefore considered the major source of human exposure (Ougier et al., 2021). BPA is also used in e.g. paints, medical devices, surface coatings and toys. BPA is immunotoxic and reprotoxic, and its use has therefore been regulated on the EU market, for example in infant feeding bottles (EFSA, 2023). BPA has partly been replaced by bisphenol S (BPS) and bisphenol F (BPF), even though possible reproductive toxic effects have been suggested also for these substances (Rochester and Bolden, 2015, Wiklund and Beronius, 2022). In January 2025, the EU Commission banned the use of BPA and other hazardous bisphenols, including BPS, in food contact materials (European Commission, 2024).

BPA and BPS were detected in almost all samples (98%) and BPF was detected in 91% of the samples. BPA was generally present at the highest concentrations of the three analysed bisphenols, but BPS were higher in 25% of the 1.5-year-olds (Table 8). The concentrations of BPA, BPS and BPF in Riksmaten Young Children were similar to the concentrations found in 4-year-olds in Stockholm between 2019 and 2022 (Lindh et al., 2022) (Appendix 2, Table A2:2). Concentrations of BPA and BPF were also similar as in adolescents in RMA, whereas BPS levels seem higher in the young children (Livsmedelsverket & Naturvårdsverket, 2020) (Appendix 2, Table A2:2). The ratios between the medians of the three substances (BPA:BPS:BPF) were 8.5:3.8:1 for 1.5-year-olds and 9.2:2.3:1 for the 4-year-olds. This was somewhat different from the ratio seen in Swedish primiparous women (3.3:1:1.2 (Gyllenhammar et al., 2023a)) and adolescents (9:1:1 (Livsmedelsverket & Naturvårdsverket, 2020)). This was mainly due to that BPS was higher than BPF in the young children whereas the opposite was true for women. Interestingly, an increasing time trend has recently been reported for BPS in primiparous women, whereas BPF and BPA seems to decrease (Gyllenhammar et al., 2023a). A decreasing trend of BPA has also been reported in Swedish 4-year-olds, whereas BPF and BPS increased slightly (Lindh et al., 2022).

HBM guidance values (HBM-GVs) have been derived within the European joint biomonitoring program HBM4EU to evaluate biomonitoring data. HBM-GVs correspond to HBM I values previously mentioned. It refers to the concentration at and below which there is no risk of health effects, and consequently no need for action, according to current knowledge (Apel et al., 2020). All participants in Riksmaten Young Children had BPA levels below the HBM-GV of 135 ng/mL established for children over 3 years of age in 2021 (Ougier et al., 2021). However, this HBM-GV corresponds to a no longer valid provisional tolerable daily intake (TDI) of 4 µg/kg body weight (bw) derived by EFSA in 2015 (EFSA, 2015). In 2023, EFSA established a new TDI based on immune effects that is 20,000 times lower than the provisional, i.e. 0.2 ng/kg bw (EFSA, 2023). Taking this new TDI into account, it can be estimated that all children with detectable concentrations of BPA in urine (98%, LOD:

0.3 ng/mL) have a higher exposure to BPA than the TDI. Similarly, EFSA concluded in their risk assessment that the mean dietary exposure to BPA in all age groups exceeds the TDI (EFSA, 2023). It should be note that the TDI set by EFSA in 2023 has been debated, and a TDI of 0.2 µg/kg bw has for example been proposed by the German Federal Institute for Risk Assessment (Bfr, 2023).

For BPS and BPF, no HBM-GV could be found for children, but for BPS an HBM-GV of 1.0 ng/mL has been suggested for adults (Meslin et al., 2022). Forty children (12%) were above this value, indicating that there is a need of continuous biomonitoring and to further reduce the exposure to PBS.

Polycyclic aromatic hydrocarbon (PAH) metabolites

Polycyclic aromatic hydrocarbons (PAHs) are formed mainly during incomplete combustion and are found in complex mixtures in the environment. Cigarette smoking is a significant source of exposure, while food and polluted air are major sources for non-smokers. The levels of PAHs are especially high in smoked and grilled foods. As PAHs are carcinogenic, the exposure should be as low as possible (EFSA, 2008)

The PAH metabolite 2,3-PHE was detected in all samples (LOD was 0.01 ng/mL) whereas only 14% of the samples had detectable levels of 1-PYR (LOD was 0.1 ng/mL) (Table 8). The concentrations in Riksmaten Young Children are in line with previously reported in 4-year-olds in Stockholm (Lindh et al., 2022) and in Swedish adolescents (Livsmedelsverket & Naturvårdsverket, 2020) (Appendix 2, Table A2:2). Decreasing time trends have been reported for both analysed PAH metabolites (Gyllenhammar et al., 2023a, Lindh et al., 2022). We could not find any human biomonitoring assessment values for PAH-metabolites to compare our data with.

Pesticide metabolites

Pesticides are used in the agriculture to control pests. In addition to occupational exposure, humans are exposed via food, mainly from vegetables, fruits and grains (Noren et al., 2020). In the present study we analysed TCP (metabolite of the pesticides chlorpyrifos), 3-PBA (metabolite of pyrethroids), OH-TEB (metabolite of tebuconazole) and OH-BOS (metabolite of boscalid) in urine. For chlorpyrifos and pyrethroids, neurotoxicity has been reported in animal studies (EFSA, 2019b, Aylward et al., 2018), whereas no long-term consumer health risk has been identified by EFSA for tebuconazole or boscalid at current exposure levels (EFSA, 2021). In Sweden, no pesticide containing chlorpyrifos has been approved since about 2010, and the use of pyrethroids has been restricted. Thus, exposure to residues of these two pesticides mainly occurs from consumption of imported fruits and vegetables. Both tebukonazole and boscalid are authorised and used by Swedish farmers, so residues may occur in both domestic and imported products. All four analysed pesticide metabolites were detected in most urine samples (≥97%) (Table 8). Whereas the concentrations of 3-PBA were similar as previously seen in Swedish 4-year-olds (Lindh et al., 2022) and adolescents (Livsmedelsverket & Naturvårdsverket, 2020), the concentrations of TCP were lower in Rikmaten Young Children compared with these studies (Appendix 2, Table A2:2). This is in

line with a decreasing time trend of urinary TCP during the latter 10-15 years (Gyllenhammar et al., 2023a, Lindh et al., 2022, Norén et al., 2024). In contrast, an increasing trend for 3-PBA has been indicated (Gyllenhammar et al., 2023a, Lindh et al., 2022, Norén et al., 2024). Increasing urinary concentrations of OH-TEB has also been reported in Swedish adolescents, while OH-BOS could not be included in that time trend analysis due to few data points (Norén et al., 2024). The median concentrations of OH-TEB and OH-BOS in Swedish adolescents (0.21 ng/mL and 0.16 ng/mL, respectively) (Norén et al., 2024) were similar as those seen in the Riksmaten Young Children.

Aylward et al (2018) derived so-called Biomonitoring Equivalent-values (BE-values) for 3-PBA in urine. They define BE-values as estimates of the concentration of a chemical or its metabolites in blood or urine that corresponds to risk assessment-derived exposure guidance values such as TDIs. BE-values should be used as screening values for the assessment of biomonitoring data to provide an initial evaluation of whether the detected concentrations are well below, near, or above the concentrations corresponding to current exposure guidance values. The definitions of BE- and HBM I-values are functionally very similar (Angerer et al., 2011). The BE-values for 3-PBA should be compared with the mean or median concentration in a population (Aylward et al., 2018). The median concentration of 3-PBA in Riksmaten Young Children (0.29 ng/mL) was less than one fifth of the most conservative BE-value of 1.7 ng/mL (based on the assumption that all 3-PBA originates from the most toxic pyrethroid), and more than 300 times lower than 87 ng/mL (BE-value weighted for relative exposure estimations of different pyrethroid compounds) (Aylward et al., 2018).

All children had concentrations of TCP in urine below a provisional HBM-GV of 10 ng/mL derived within HBM4EU (Govarts et al., 2023), and the highest measured concentration measured in Riksmaten Young Children was 4.4 ng/mL.

We could not find any human biomonitoring assessment values for OH-TEB or OH-BOS to compare our data with.

Fragrance metabolites

Two fragrance metabolites were analysed in Riksmaten Young Children, 4-isopropylbenzoic acid (IPBA) and 4-tert-butylbenzoic acid (TBBA).

IPBA is a urinary metabolite of several fragrances, including p-cymene. P-cymene (1-isopropyl-4-metylbensen) is used in cosmetics, cleaning agents, polishes and wax blends, personal care products etc. (Swedish Chemicals Agency, 2023a). P-cymene is also naturally occurring in plants, including cinnamon, nutmeg, grapefruit, and tangerine, and in tea tree oil (Balahbib et al., 2021, de Groot and Schmidt, 2016). In addition, p-cymene is a flavouring approved for use in food within the European Union (Regulation (EC) No 1334/2008). The Swedish Chemicals Agency has raised concern about and proposed a harmonised classification of four fragrances (including p-cymene) and IPBA as toxic to reproduction (Swedish Chemicals Agency, 2023a) and a similar classification of tea tree oil is also discussed.

IPBA was detected in 93% of the urine samples in Riksmaten Young Children (Table 8). To our knowledge, there are no other studies of IPBA in human urine.

TBBA is the main urinary metabolite of 2-(4-*tert*-butylbenzyl) propionaldehyde, also known as lysmeral. Lysmeral is a synthetic fragrance used in several consumer products such as cleaning agents, perfumes, cosmetics, personal care products, and air fresheners (Scherer et al., 2017). Both lysmeral and TBBA are classified as toxic to reproduction and the Swedish Chemicals Agency has proposed a harmonised classification and labelling of TBBA, lysmeral and four other substances forming TBBA (Swedish Chemicals Agency, 2023b). It should be noted that TBBA is not specific to lysmeral but can also be excreted after uptake of TBBA itself or of other precursors (Scherer et al., 2017).

TBBA was detected in 89% of the urine samples in Riksmaten Young Children (Table 8). To our knowledge, there is no other published data on TBBA in urine from the Swedish population, but TBBA and other lysmeral metabolites were analysed in different age groups in Germany (Murawski et al., 2020). The median TBBA concentration in the present study (6.2 ng/mL) is lower than the median concentration of 10.7 ng/mL in urine from 3- to 5-year-olds in Germany sampled in 2014-2017 (Murawski et al., 2020).

We could not find any human biomonitoring assessment values for IPBA or TBBA to compare our data with.

Triclosan (TCS) and benzophenone-3 (BP-3)

TCS is an antibacterial agent used in for example personal care products like toothpaste, shower gel and cosmetic products while BP-3 is widely used as UV filter in sunscreens and cosmetics to prevent sunburn and skin damage (Apel et al., 2017, Mustieles et al., 2023). Concern about both TCS and BP-3 has been raised because of their potentially endocrine disrupting properties (Mustieles et al., 2023, SCCS, 2022).

25% of the urine samples had detectable concentrations of the antibacterial agent TCS (LOD: 0.2 ng/mL). For BP-3, about half of the samples were above LOD of 0.5 ng/mL (Table 8).

Both TCS and BP-3 concentrations in urine in Riksmaten Young Children were lower than in other Swedish 4-year-olds (Lindh et al., 2022) and adolescents (Livsmedelsverket & Naturvårdsverket, 2020) (Appendix 2, Table A2:2). A declining trend of TCS in urine has been reported in Swedish primiparous women (Gyllenhammar et al., 2023a), whereas a decline of TCS was seen in 4-year-olds until 2015, whereafter it seems unchanged (Lindh et al., 2022). There was no time trend of BP-3 in Swedish primiparous women (Gyllenhammar et al., 2023a).

The highest measured TCS concentration of 7 ng/mL was far below the HBM I value for children (2000 ng/mL) based on haemato/spleen-toxicity as critical effect (Apel et al., 2017). For BP-3, there is only a provisional HBM-GV for creatinine-adjusted urine concentrations for teenagers and adults (Govarts et al., 2023).

Table 8. Density-adjusted concentrations of organophosphate flame retardant metabolites, bisphenols, pesticide metabolites etc. (ng/mL) in urine from Swedish 1.5- and 4-year-olds (N=334, whereof 61 1.5-year-olds and 273 4-year-olds) participating in Riksmaten Young Children. Concentrations below LOD were replaced by LOD/√2 in the calculations.

Substance	LOD	% of samples <LOD	Age group	N[1]	AM	SD	GM	5th perc	Median	95th perc	P[2]
Organophosphate flame retardant metabolites											
BBOEP	0.03	40	Both	334	0.30	2.76	0.07	<LOD	0.05	0.76	
			1.5 yrs	61	0.98	6.42	0.08	<LOD	0.05	0.71	
			4 yrs	273	0.15	0.27	0.07	<LOD	0.05	0.76	0.181
BDCIPP	0.1	9	Both	334	0.94	1.83	0.57	0.18	0.51	3.07	
			1.5 yrs	61	0.52	0.32	0.44	0.16	0.45	0.95	
			4 yrs	273	1.04	2.00	0.60	0.19	0.53	3.58	0.009
DPP	0.03	0	Both	333	1.87	2.52	1.32	0.41	1.23	4.80	
			1.5 yrs	61	1.95	2.87	1.31	0.41	1.21	4.26	
			4 yrs	272	1.86	2.44	1.32	0.41	1.23	4.97	0.998
Bisphenols											
BPA	0.3	2	Both	334	1.76	5.08	1.11	0.49	1.01	3.8	
			1.5 yrs	61	2.64	6.52	1.34	0.56	1.18	5.4	
			4 yrs	273	1.56	4.69	1.06	0.45	0.99	3.7	0.012
BPS	0.02	2	Both	334	0.68	2.16	0.29	0.06	0.28	2.42	
			1.5 yrs	61	1.76	4.77	0.54	0.07	0.53	6.43	
			4 yrs	273	0.44	0.62	0.26	0.05	0.25	1.49	<0.001
BPF	0.04	9	Both	334	0.28	0.75	0.13	0.04	0.11	0.70	
			1.5 yrs	61	0.45	1.06	0.17	0.05	0.14	2.31	
			4 yrs	273	0.25	0.66	0.13	0.04	0.11	0.61	0.028
Polycyclic aromatic hydrocarbon (PAH) metabolites											
2,3-PHE	0.01	0	Both	333	0.18	0.25	0.13	0.05	0.12	0.50	
			1.5 yrs	61	0.18	0.22	0.13	0.05	0.12	0.35	
			4 yrs	272	0.18	0.25	0.13	0.05	0.12	0.50	0.946
1-PYR	0.1	86	Both	334	0.10	0.09	0.09	<LOD	<LOD	0.22	
			1.5 yrs	61	0.12	0.07	0.10	<LOD	0.10	0.22	
			4 yrs	273	0.10	0.10	0.08	<LOD	<LOD	0.22	nd
Pesticide metabolites											
TCP	0.05	0.3	Both	334	0.59	0.53	0.46	0.17	0.41	1.67	
			1.5 yrs	61	0.48	0.42	0.37	0.13	0.35	1.18	
			4 yrs	273	0.61	0.55	0.48	0.19	0.43	1.69	0.003
3-PBA	0.04	3	Both	334	0.47	0.59	0.32	0.10	0.29	1.34	
			1.5 yrs	61	0.45	0.73	0.26	0.08	0.22	1.24	
			4 yrs	273	0.47	0.55	0.33	0.10	0.30	1.34	0.037

Substance	LOD	% of samples <LOD	Age group	N[1]	AM	SD	GM	5th perc	Median	95th perc	P[2]
OH-TEB	0.03	2	Both	334	0.45	1.39	0.22	0.07	0.18	1.12	
			1.5 yrs	61	0.18	0.18	0.14	0.05	0.13	0.43	
			4 yrs	273	0.51	1.52	0.24	0.08	0.21	1.37	<0.001
OH-BOS	0.03	1	Both	334	0.80	1.74	0.34	0.07	0.28	3.12	
			1.5 yrs	61	0.52	1.00	0.22	0.04	0.17	1.90	
			4 yrs	273	0.87	1.86	0.37	0.07	0.30	3.22	0.001
Fragrance metabolites											
IPBA	3.0	7	Both	334	42.2	114	14.2	<LOD	12.2	217	
			1.5 yrs	61	68.3	194	19.9	3.36	16.6	305	
			4 yrs	273	36.4	85.8	13.2	<LOD	11.0	210	0.040
TBBA	1.5	11	Both	334	13.4	37.8	6.49	<LOD	6.23	40.9	
			1.5 yrs	61	13.9	20.8	8.16	1.5	7.93	43.2	
			4 yrs	273	13.3	40.7	6.16	<LOD	5.85	36.7	0.141
Triclosan (TCS) and benzophenone-3 (BP-3)											
BP-3	0.5	40	Both	334	2.46	8.04	1.00	<LOD	0.77	6.77	
			1.5 yrs	61	4.62	15.6	1.45	<LOD	1.21	10.4	
			4 yrs	273	1.98	4.94	0.92	<LOD	0.73	6.51	0.005
TCS	0.2	75	Both	334	0.27	0.49	0.20	<LOD	<LOD	0.72	
			1.5 yrs	61	0.27	0.18	0.23	<LOD	0.22	0.67	
			4 yrs	273	0.27	0.54	0.19	<LOD	<LOD	0.72	nd

LOD limit of detection; AM arithmetic mean; SD standard deviation; GM geometric mean; perc percentile; nd not determined (because more than 30% of the samples had concentrations below LOD); abbreviations of compounds are referred to table 2.

[1]Due to large matrix effects, some analytes could not be determined in all samples

[2]p-values for differences between age groups (from Analysis of Variance [ANOVA] with natural log-transformed concentrations and with the factors age group, gender and region in the models).

6.5.2 Age and gender differences

The small number of urine samples from 1.5-year-olds limited the likelihood to detect age differences in urine concentrations of organic contaminants. However, mean and median concentrations of all three bisphenols were higher in 1.5-year-olds than in 4-year-olds (Table 8). The reasons for these age differences are unknown, but it is possible that younger children have a higher exposure from toys and dust than older children, and there may also be differences in dietary habits (such as canned baby food) and amounts consumed per kg body weight between the age groups.

Concentrations of all four pesticide metabolites (TCP, 3-PBA, OH-TEB, OH-BOS) were higher in urine from 4-year-olds than in samples from 1.5-year-olds (Table 8). The reason for this finding may be differences in dietary habits.

In additions to the age differences for bisphenols and pesticide metabolites, concentrations of three of the phthalate metabolites (MBzP, MnBP, cx-MiDP), the fragrance metabolite IPBA and BP-3 were higher in 1.5-year-olds than in 4-year-olds (Table 7 & Table 8), while concentrations of the organophosphate flame retardant metabolite BDCIPP were higher in 4-year-olds (Table 8). The reasons for these seemingly random age differences are unknown and may be due to chance.

There were no significant gender differences in exposure to the analysed compounds, except for a slightly higher concentration of OH-BOS in girls than in boys (mean concentration 0.54 versus 0.37 ng/mL, p=0.002). This difference may also be due to chance as a consequence of multiple statistical testing.

Age and gender differences were not evaluated for BBOEP, 1-PYR, BP-3 and TCS because of the large number of samples with concentrations below LOD (>30%).

6.5.3 Regional differences

Similar to what was observed in RMU (Livsmedelsverket & Naturvårdsverket, 2020), there were no consistent regional patterns in concentrations of organic contaminants in urine, and all observed regional differences were small. For example, we observed small but significant regional differences in urine concentrations of the phthalate metabolites MEP, MBzP, MnBP, MiBP, 5-oxo-MEHP, 5-OH-MEHP, 5-cx-MEPP, OH-MiNP, cx-MiDP and the DiNCH metabolite cx-MiNCH (Figure 7 & Figure 8), while there were no regional trends for MnHxP, oxo-MiNP, cx-MiNP, OH-MPHP or OH-MiNCH (Appendix 3, Figure A3:1). For the other analysed substances/metabolites, there were significant regional differences for BBOEP, BDCIPP, 2,3-PHE and TCP (Figure 8), but no trends for DPP, BPA, BPS, BPF, 3-PBA, OH-TEB, OH-BOS, IPBA, TBBA or BP-3 (Appendix 3, Figure A3:1 & Figure A3:2). The number of samples per region, especially from Umeå (N=18), was small limiting the likelihood to detect any possible differences. Trends for 1-PYR and TCS were not evaluated because of the large fraction of samples with concentrations below LOD.

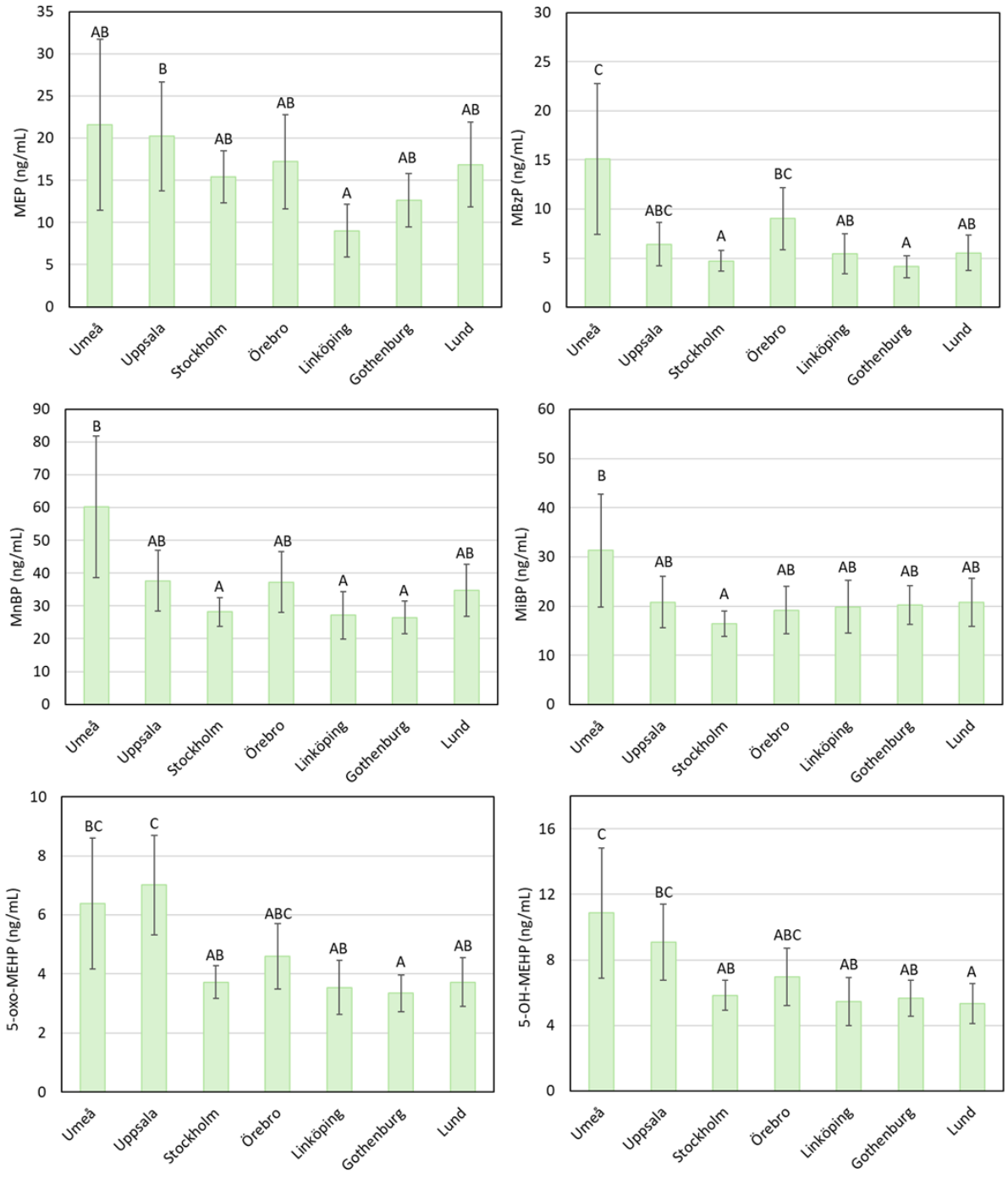

Figure 7. Density-adjusted concentrations of the phthalate metabolites MEP, MBzP, MnBP, MiBP, 5-oxo-MEHP and 5-OH-MEHP in urine from Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region, age group and gender). Different letters above the bars indicate significant differences between regions ($p<0.05$) according to Tukey's multiple comparison test. Number of observations per region: Umeå N=18, Uppsala N=37-39, Stockholm N=96-97, Örebro N=38, Linköping N=33, Gothenburg N=64, Lund N=45.

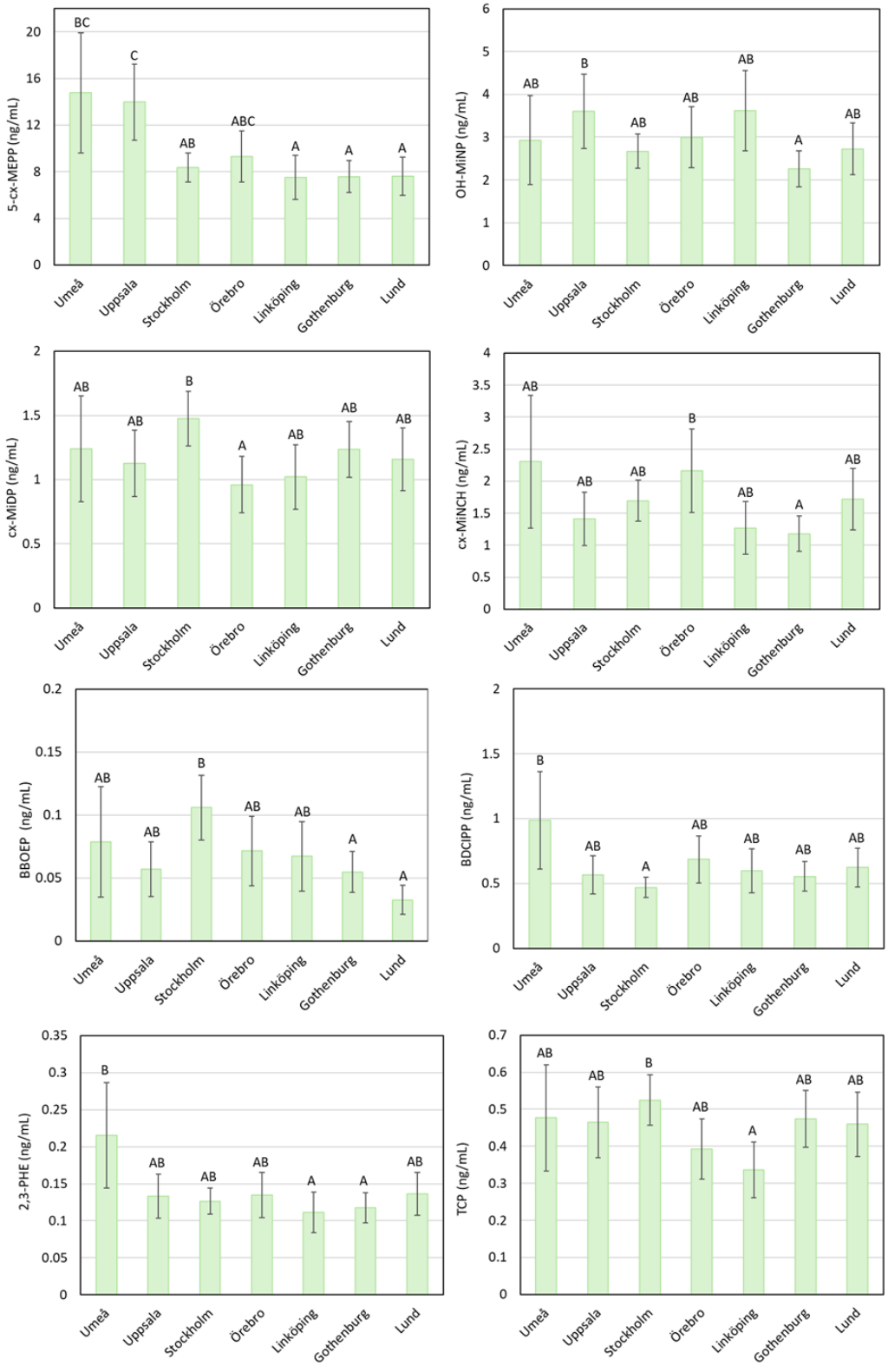

Figure 8. Density-adjusted concentrations of phthalate- and DiNCH-metabolites, BBOEP, BDCIPP, 2,3-PHE and TCP in urine from Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region, age group and gender). Different letters above the bars indicate significant differences between regions ($p<0.05$) according to Tukey's multiple comparison test. Umeå N=17-18, Uppsala N=37-39, Stockholm N=93-97, Örebro N=38, Linköping N=33, Gothenburg N=62-64, Lund N=44-45.

6.5.4 Conclusions

Urine concentrations of several organic contaminants were determined in the children in Riksmaten Young Children, i.e. metabolites of phthalates, DiNCH, organophosphate flame retardants, PAH, pesticides, and fragrances, as well as bisphenols, an antibacterial agent and a UV filter agent. Most metabolites and compounds could be detected in a majority of the samples. This indicates a continuous exposure since the analysed compounds are short-lived and excreted rapidly from the body. However, exceptions were the organophosphate flame retardant metabolite BBOEP, the PAH metabolite 1-PYR, the antibacterial agent TCS and the UV filter BP-3, for which 40-86% of the samples were below LOD.

In general, the determined concentrations were in line with, or lower, than previously observed concentrations in Swedish pre-school children or adolescents (Appendix 2). Comparisons of urine concentrations in Riksmaten Young Children with available human biomonitoring assessment values mostly indicated that there is likely no risk of adverse health effects.

Of the phthalate metabolites, MnBP was found at the highest concentrations. The 95th percentiles of all analysed phthalate metabolites and DiNCH metabolites were below the HBM I values, indicating low risk of adverse health effects. However, the 95th percentile of MnBP (metabolite of DnBP) in 1.5-year-olds was above the HBM I (161 ng/mL versus 120 ng/mL).

BPA showed the highest concentrations of the bisphenols, but BPS was higher in 25% of the 1.5 -year-olds. The 1.5-year-olds had higher levels of all three bisphenols compared to the 4-year-olds. For BPA, urine levels suggest that exposure is higher than what EFSA considers tolerable. In January 2025, the EU Commission banned the use of BPA and other hazardous bisphenols, including BPS, in food contact materials. This will likely decrease the exposure in the future.

All four analysed pesticide metabolites were detected in most urine samples. Comparison between the measured median concentration of 3-PBA and the derived biomonitoring equivalence value, indicated that there is no health risk from 3-PBA exposure. 4-year-olds had higher levels of all four pesticide metabolites compared to the 1.5-year-olds.

There is limited knowledge of human urinary concentrations of the fragrance metabolites IPBA and TBBA. Both these compounds could be detected in about 90% of the samples.

7. Discussion

Riksmaten Young Children provides novel information about exposure to metals, PFAS, the fungicide chlorothalonil and several short-lived organic contaminants in 1.5- and 4-year-olds at a national level. Biomonitoring in this age group is of special interest as children may be more susceptible to adverse effects caused by toxic substances. Exposure data in 1.5-year-olds are limited both in Sweden and other countries, to our knowledge. Further, Riksmaten Young Children provides novel data which is highly relevant because changes in regulations and legislation of substances have an impact on their presence in e.g. foods over time.

Even though the sample is geographically distributed over Sweden, data is limited to children living within 50 km of Umeå, Uppsala, Stockholm, Örebro, Linköping, Gothenburg and Lund, due to practical reasons during sampling. Therefore, children living in rural areas may be underrepresented. Further, the number of 1.5-year-olds with urine concentrations of organic contaminants is relatively small compared to the 4-year-olds, since most of the participants in the youngest age group used diapers and did therefore not donate any urine. Associations between exposure to contaminants and dietary habits and other lifestyle factors are not included in this report.

7.1 Overall conclusions

Most children had detectable concentrations of metals, PFAS, the fungicide metabolite HCT and most of the analysed short-lived organic contaminants in blood or urine. The levels were generally comparable to those found in other studies and within the expected range. The levels of mercury, triclosan, and metabolites of phthalates, DiNCH and pyrethroids (3-PBA) in all or most children were lower than the proposed concentrations below which it is unlikely that these contaminants cause adverse health effects. Notably, some participants exhibited higher exposure to lead and PFAS than their human biomonitoring assessment values. Also, EFSA has concluded that BPA exposure is too high and the urine concentrations in Riksmaten Young Children confirm this conclusion. This underlines the importance of further reducing exposure to lead, PFAS and BPA, from all sources. We cannot exclude that there are populations of children with a higher exposure to contaminants than the participants in Riksmaten Young Children. Full risk assessments of the observed concentrations were beyond the scope of this report.

Compound specific conclusions are:

- Comparisons with human biomonitoring assessment values show that, based on current knowledge, the exposure to mercury in Swedish children is not a health concern.
- There is currently no assessment value for cadmium in children to compare our data with, but the observed blood concentrations were within the expected range.

- For lead, 10% of the participants had blood concentrations above EFSA's reference point for developmental neurotoxicity in small children. This underlines the importance of further reducing lead exposure from all sources.
- PFOS, PFOA and PFHxS were the PFAS found in highest concentrations in serum. 4.5% of the 1.5-year-olds had concentrations of ΣPFAS4 above the health-based reference point in 1-year-old children that EFSA uses as starting point for deriving a tolerable weekly intake.
- All analysed metabolites of phthalates and DiNCH could be detected in most urinary samples (>99%). The 95th percentiles of these were below the HBM I value, indicating no risk of adverse health effects. To our knowledge, MnHxP has not previously been analysed in Swedish urine samples.
- BPA was generally present at the highest concentrations of the three bisphenols, but BPS concentrations were higher than BPA in 25% of the 1.5 -year-olds. For BPA, urine levels suggest that exposure is higher than what EFSA considers tolerable.
- All four analysed pesticide metabolites were detected in most urine samples. A biomonitoring equivalence value has been derived for 3-PBA, and a comparison with this value indicated no risk.
- There is limited knowledge about human serum concentrations of the fungicide metabolite HCT and of human urinary concentrations of the fragrance metabolites IPBA and TBBA. HCT was found in all serum samples, and IPBA and TBBA were detected in about 90% of the urine samples. These findings show that it is important with biomonitoring of substances that have not previously been analysed to gain knowledge about exposure.
- For substances where foetal and breastfeeding exposure is important, i.e. PFAS and HCT, we observed higher levels in 1.5-year-olds than in 4-year-olds. This clearly shows that women's exposure to certain substances is important to protect foetuses and infants.
- Highest exposure to PFAS was detected in children from Uppsala and Stockholm where the drinking water levels of these compounds have been elevated. Other observed regional differences were not consistent, and the findings may be random.

8. Contributors

Several colleagues at the Swedish Food Agency were involved in the planning and implementation of Riksmaten Young Children, including handling of samples – Lotta Moraeus, Eva Warensjö Lemming, Karin Stenberg, Elin Larsson, Sandra Ahlborg, Emma Patterson, Anna Karin Lindroos, Lina Johansson, Sofia Alvarez Nordström, Christina Martin and Jannica Bergman.

The regional Environmental and Occupational Medicine (EOM) clinics in Umeå, Stockholm, Örebro, Linköping, Gothenburg and Lund were responsible for the sampling of blood and urine. We would also like to thank Professor Karl Michaëlsson (Department of Surgical Sciences, Uppsala University) for generously allowing us to use the clinic in Uppsala for blood sampling.

Maria Kippler was responsible for the chemical analyses of metals and Michael Levi performed the metal analysis (both at Institute of Environmental Medicine, Karolinska Institutet). Christian Lindh was responsible for the analyses of PFAS and organic contaminants in urine and Anna Rönnholm performed these analyses (both at Division of Occupational and Environmental Medicine, Lund University). Maria Kippler and Christian Lindh also reviewed the sections about metals and PFAS/organic contaminants in urine, respectively.

We would also like to thank Peter Ridefelt, MD and Associate Professor at Department of Medical Sciences, Uppsala University for contributing with his medical expertise.

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10. Appendices

10.1 Appendix 1

Table A1:1. Estimation of precision across all metal analysis using two commercial Seronorm references materials from Sero As, Billingstad, Norway. LOD=limit of detection, CV=coefficient of variation.

Metal/element	LOD	Seronorm L1-WB 2011920		Seronorm L2-WB 2011921	
	(µg/L)	Reference value (µg/L)	CV (%)	Reference value (µg/L)	CV (%)
Arsenic	0.054	2.5±0.5	14	11.4±2.3	6
Cadmium	0.021	0.29±0.06	15	5.0±1.0	12
Cobalt	0.039	0.20±0.04	28	5.1±1.0	7
Mangenese	0.23	16.3±3.3	6	22.5±1.0	8
Mercury	0.089	1.63±0.33	12	15.0±3.0	16
Lead	0.048	10.3±2.1	5	295±30	6

Table A1:2. Estimation of between-run precision in the analyses of PFAS and HCT using two homemade pooled serum samples as quality controls (QC1 and QC2). LOD=limit of detection, CV=coefficient of variation. Abbreviations of compounds are referred to Table 1.

Compound	LOD (µg/L)	Concentration QC1 (µg/L)	CV QC1 (%)	Concentration QC2 (µg/L)	CV QC2 (%)
PFBS	0.01	0.4	4	1.8	4
PFPeS	0.05	0.5	10	2.0	12
PFHpA	0.01	0.6	5	2.3	7
PFHxS	0.03	0.8	8	2.7	5
PFOA	0.01	1.6	6	3.8	7
PFHpS	0.02	0.4	10	2.1	11
PFNA	0.02	1.1	5	2.7	8
tot-PFOS	0.05	4.1	3	11	5
br-PFOS	0.05	0.9	9	3.2	3
lin-PFOS	0.05	2.8	10	8.3	5
PFDA	0.04	0.8	8	2.2	8
PFUnDA	0.07	0.7	10	2.2	8
HCT	0.06	5.2	3	3.3	4

Table A1:3. Estimation of between-run precision and accuracy in the analyses of PFAS using two reference samples originating from the EU-project HBM4EU and prepared as quality controls (HBM4EU QC1 and HBM4EU QC2). Concentrations, expected concentrations and CV (coefficient of variation) in N=8 repeated analyses are shown. Abbreviations of compounds are referred to Table 1.

Compound	Concentration HBM4EU QC1 (µg/L)	Expected conc HBM4EU QC1 (µg/L)	CV HBM4EU QC1 (%)	Concentration HBM4EU QC2 (µg/L)	Expected conc HBM4EU QC2 (µg/L)	CV HBM4EU QC2 (%)
PFHpA	0.4	0.4	7	1.1	1.0	8
PFHxS	0.7	0.7	5	1.3	1.3	4
PFOA	2.1	2.1	3	3.6	3.7	6
PFHpS	0.2	0.2	3	0.5	0.4	3
PFNA	0.6	0.6	9	1.1	1.1	6
Total-PFOS	3.0	3.0	4	4.6	4.7	4
PFDA	0.6	0.5	8	1.0	0.9	8
PFUnDA	0.4	0.3	9	0.6	0.6	8

Table A1:4. Estimation of between-run precision in the analyses of organic contaminants in urine using two homemade pooled urine samples as quality controls (QC1 and QC2). LOD=limit of detection, CV=coefficient of variation. Abbreviations of compounds are referred to Table 2.

Compound	LOD (µg/L)	Concentration QC1 (µg/L)	CV QC1 (%)	Concentration QC2 (µg/L)	CV QC2 (%)
MEP	0.1	3.3	15	424	8
MnHxP	0.08	-	-	-	-
MBzP	0.06	1.0	17	9	16
MnBP	0.4	145	8	520	10
MiBP	0.6	5	11	3.3	16
5-oxo-MEHP	0.03	1.0	26	53	20
5-OH-MEHP	0.06	1.4	16	51	12
5-cx-MEPP	0.03	2.7	11	13	9
oxo-MiNP	0.03	2.5	11	11	8
OH-MiNP	0.04	17	22	73	19
cx-MiNP	0.06	32	9	69	10
cx-MiDP	0.20	7.8	16	39	15
OH-MPHP	0.04	9.4	12	52	10
cx-MiNCH	0.03	9.7	10	54	16
OH-MiNCH	0.03	13	11	62	6
BBOEP	0.03	0.9	6	4.7	4
BDCIPP	0.10	1.0	11	5.0	14
DPP	0.03	1.2	8	5.1	7
BPA	0.30	6	10	29	7
BPS	0.02	6.2	7	31	5
BPF	0.04	0.3	15	32	7
2,3-PHE	0.01	3.6	10	4.5	10
1-PYR	0.10	0.4	13	2.3	14
TCP	0.05	5.6	6	26	5
3-PBA	0.04	5.1	4	27	4
OH-TEB	0.03	-	-	-	-
OH-BOS	0.03	-	-	-	-
BP-3	0.5	60	6	65	5
TCS	0.2	15	21	18	13
IPBA	3.0	8.9	21	22	18
TBBA	1.5	3.7	43	2.6	36

Table A1:5. Estimation of between-run precision and accuracy in the analyses of organic contaminants in urine using two reference samples originating from G-EQUAS and prepared as quality controls (G-EQUAS QC1 and QC2). Concentrations, expected concentrations and CV (coefficient of variation) in N=8 repeated analyses are shown. Abbreviations of compounds are referred to Table 2.

Compound	Concentration G-EQUAS QC1 (µg/L)	Expected conc G-EQUAS QC1 (µg/L)	CV G-EQUAS QC1 (%)	Concentration G-EQUAS QC2 (µg/L)	Expected conc G-EQUAS QC2 (µg/L)	CV G-EQUAS QC2 (%)
MEP	40	39	6	122	132	14
MnHxP	-	-	-	-	-	-
MBzP	1.8	1.8	10	2.8	2.6	9
MnBP	3.4	3.4	5	4.2	3.3	12
MiBP	2.6	2.1	9	64	64	10
5-oxo-MEHP	2.1	2.3	22	20	19	26
5-OH-MEHP	3.4	3.9	25	33	36	8
5-cx-MEPP	3.2	3.6	8	32	34	5
oxo-MiNP	11	11	8	52	49	11
OH-MiNP	11	10	24	185	172	18
cx-MiNP	6.9	5.1	12	68	58	7
cx-MiDP	-	-	-	-	-	-
OH-MPHP	-	-	-	-	-	-
cx-MiNCH	0.9	1.0	7	5.3	5.4	13
OH-MiNCH	4.5	4.2	9	1.1	1.1	6
BBOEP	-	-	-	-	-	-
BDCIPP	-	-	-	-	-	-
DPP	-	-	-	-	-	-
BPA	3.3	3.2	4	14.8	14.6	9
BPS	0.6	0.6	8	3.3	3.3	4
BPF	0.6	0.7	4	2.4	2.4	9
2.3-PHE	0.1	0.1	10	1.6	1.6	5
1-PYR	0.3	0.2	7	0.5	0.6	14
TCP	2.0	1.9	5	9.9	9.6	8
3-PBA	3.0	3.0	3	8.6	8.5	5
OH-TEB	-	-	-	-	-	-
OH-BOS	-	-	-	-	-	-
BP-3	3.6	3.9	4	16	17	5
TCS	2.3	25	21	199	195	8
IPBA	-	-	-	-	-	-
TBBA	-	-	-	-	-	-

10.2 Appendix 2

Table A2:1. Comparisons between urine concentrations of phthalate metabolites and DiNCH metabolites in Riksmaten Young Children and three other Swedish studies in pre-school children and adolescents.

Substance	Riksmaten Young Children (N=334)[1]		Pre-school children in Eskilstuna/Vingåker (N=54)[2]		4-year-olds in Stockholm (N=69)[3]		Riksmaten Adolescents (N~1100)[4]	
	AM	**Median**	**AM**	**Median**	**AM**	**Median**	**AM**	**Median**
Phthalate metabolites								
MEP	34	14	47	16			112	33
MBzP	13	4.8	31	17	13	4.5	13	6.5
MnBP + MiBP	74	53	69	55			52	40
5-oxo- MEHP	6.0	3.9	15	11			9.4	6.0
5-OH-MEHP	9.0	6.3	21	15			12	7.7
5-cx-MEPP	12	8.0	19	16	17	9.9	11	6.9
oxo-MiNP	3.3	2.1	6.7	4.0			4.5	1.8
OH-MiNP	3.7	2.9	14	9.3			11	3.7
cx-MiNP	9.7	5.7	18	11	29	6.7	16	5.9
cx-MiDP	1.8	1.1	1.5	0.87	1.4	0.83	0.6	0.4
OH-MPHP	0.85	0.47	4.9	2.7	3.6	2.1	1.9	1.0
DiNCH metabolites								
cx-MiNCH	3.1	1.4			4.6	2.8	3.1	0.8
OH-MiNCH	7.3	3.0	4.4	1.7	5.7	3.0	3.5	0.8

AM, arithmetic mean. Abbreviations of compounds are referred to table 2.

[1]Includes both 1.5-year-olds (N=61) and 4-year-olds (N=273).

[2]Collected in Eskilstuna/Vingåker during 2016. Specific-gravity adjusted concentrations. Mean age ± standard deviation: 5.1 ± 0.94 years (Sjostrom et al., 2023).

[3]Collected in Stockholm between 2019 and 2021. Density-adjusted concentrations. Mean age ± standard deviation: 4.3 ± 0.33 years (Lindh et al., 2022).

[4]National sample collected between 2016 and 2017. Density-adjusted concentrations. Age between 10 and 21 years with an average of 14.7 years (Livsmedelsverket & Naturvårdsverket, 2020).

Table A2:2. Comparisons between urine concentrations of organic contaminants in Riksmaten Young Children and two other Swedish studies in pre-school and adolescents.

Substance	Riksmaten Young Children (N=334)[1]		4-year-olds in Stockholm (N=69)[2]		Riksmaten Adolescents (N~1100)[3]	
	AM	Median	AM	Median	AM	Median
Phosphorous flame retardants						
BBOEP	0.30	0.05	0.44	0.23	0.1	0.1
BDCIPP	0.94	0.51	1.3	0.3		
DPP	1.9	1.2	2.1	1.4	2.7	1.9
Bisphenols						
BPA	1.8	1.0	1.2	0.72	1.4	0.9
BPS	0.68	0.28	0.46	0.35	0.3	0.1
BPF	0.28	0.11	0.69	0.19	0.8	0.1
Polycyclic aromatic hydrocarbon (PAH) metabolites						
2.3-PHE	0.18	0.12	0.18	0.14	0.3	0.2
1-PYR	0.10	<LOD	0.08	0.06	0.1	<LOD
Pesticide metabolites						
TCP	0.59	0.41	1.4	0.8	1.8	1.2
3-PBA	0.47	0.29	0.51	0.38	0.4	0.3
OH-TEB	0.45	0.18				
OH-BOS	0.80	0.28				
Other contaminants						
BP-3	2.5	0.77	4.4	1.3	12	0.8
TCS	0.27	<LOD	0.98	0.2	3.8	0.3

AM. arithmetic mean. Abbreviations of compounds are referred to table 2.

[1]Includes both 1.5-year-olds (N=61) and 4-year-olds (N=273).

[2]Collected in Stockholm between 2019 and 2021. Density-adjusted concentrations. Mean age ± standard deviation: 4.3 ± 0.33 years (Lindh et al., 2022).

[3]National sample collected between 2016 and 2017. Density-adjusted concentrations. Age between 10 and 21 years with an average of 14.7 years (Livsmedelsverket & Naturvårdsverket, 2020).

10.3 Appendix 3

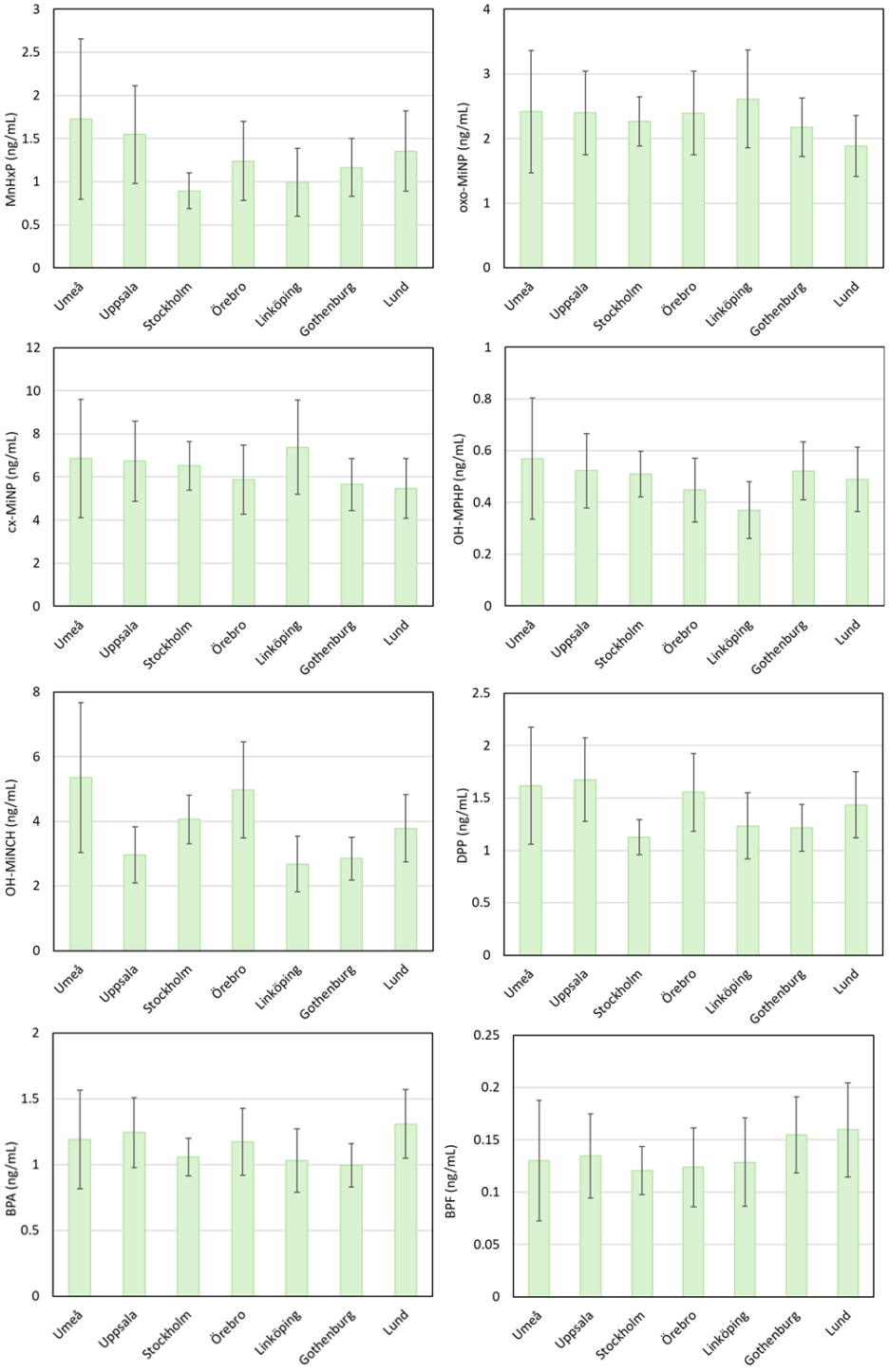

Figure A3:1. Density-adjusted concentrations of phthalate- and DiNCH-metabolites, DPP, BPA and BPF in urine from Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region. age group and gender). There are no significant differences between regions ($p>0.05$) according to Tukey's multiple comparison test. Umeå N=17-18. Uppsala N=38-39. Stockholm N=95-97. Örebro N=38. Linköping N=33. Gothenburg N=64. Lund N=45.

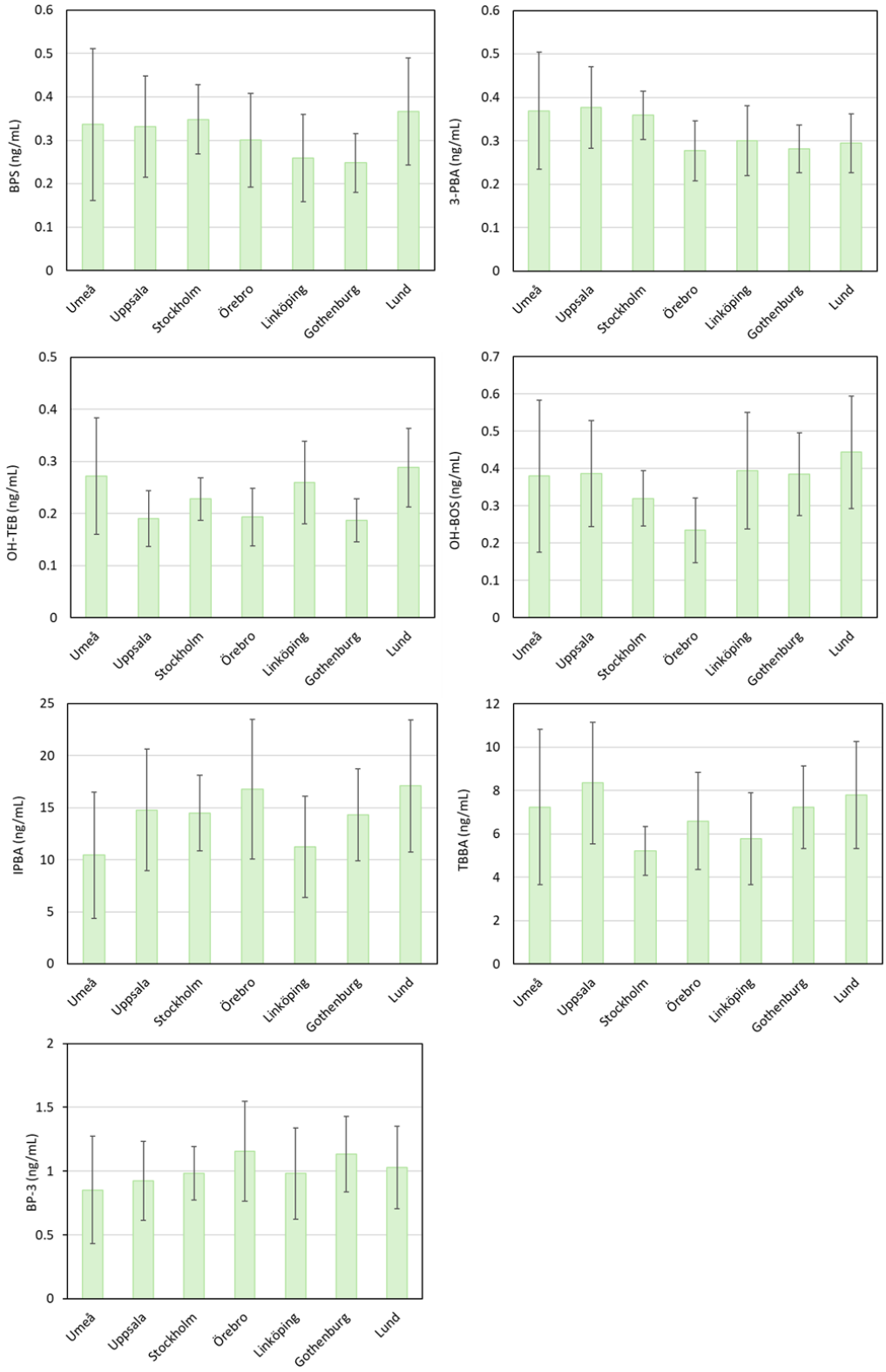

Figure A3:2. Density-adjusted concentrations of organic contaminants in urine from Swedish 1.5- and 4-year-olds participating in Riksmaten Young Children (back-transformed least square means with 95% confidence intervals estimated by ANOVA including region. age group and gender). There are no significant differences between regions ($p>0.05$) according to Tukey's multiple comparison test. Umeå N=18. Uppsala N=39. Stockholm N=97. Örebro N=38. Linköping N=33. Gothenburg N=64. Lund N=45.


Livsmedelsverket