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Risk assessment of dietary cadmium exposure in the Norwegian population

Opinion of the Panel on Contaminants of the Norwegian Scientific Committee for Food Safety

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Assessed and approved

The opinion has been assessed and approved by Panel on Contaminants. Members of the panel are: Janneche Utne Skåre (chair), Heidi Amlund, Anne Lise Brantsæter, Gunnar Sundstøl Eriksen, Christiane Kruse Fæste, Helle K. Knutsen, Helen Engelstad Kvalem, Christopher Owen Miles, Hedvig Nordeng, Irma Oskam, Anders Ruus, and Cathrine Thomsen.

Acknowledgment

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed a project group consisting of VKM members and staff to answer the request from the Norwegian Food Safety Authority. Project leader from the VKM secretariat has been Edel Holene. The members of the project group Helle K. Knutsen (chair), Heidi Amlund, Anne Lise Brantsæter, Christiane Kruse Fæste, and Anders Ruus, as well as the VKM staff Dagrun Engeset and Inger Therese L. Lillegaard, are acknowledged for their valuable work on this opinion. The National Institute of Nutrition and Seafood Research is acknowledged for providing data on concentrations of cadmium in fish filet and crabs. The Panel on Contaminants is acknowledged for their comments and views on this opinion.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

Request from the Norwegian Food Safety Authority (NFSA)

The Norwegian Food Safety Authority requested the Norwegian Scientific Committee for Food Safety (VKM) to evaluate whether Norwegians in general or subgroups in the population could be expected to have different dietary exposure to cadmium than reported for other European population groups. Furthermore, VKM was asked to assess the potential health risk of cadmium exposure from brown meat of crabs and to identify how much crab can be eaten by children and adults without exceedance of the tolerable intake for cadmium. Finally, VKM was asked to identify other particular food items which would lead to an added cadmium exposure in Norway. The Norwegian Food Safety Authority intends to use the risk assessment as a basis for the Norwegian contribution to the ongoing legislative work in the EU and to consider the necessity to adjust the existing national dietary advices or to issue new ones.

How VKM has addressed the request

VKM appointed a working group consisting of members of the Panel on Contaminants to answer the request. The Panel on Contaminants has reviewed and revised the draft prepared by the working group and finally approved the risk assessment on dietary cadmium intake in the Norwegian population.

What cadmium is and its toxicity to humans

Cadmium (Cd) is a heavy metal found as an environmental contaminant, both through natural occurrence and from industrial and agricultural sources.

Humans are exposed to cadmium by food, water and air, with food as the most important source in non-smokers. Cadmium accumulates especially in the kidneys and in liver. The amount of cadmium in the body increases continuously during life until the age of about 60-70 years, from which it levels off. The most well characterised chronic toxic effects resulting from cadmium exposure are on kidneys and bones.

The tolerable weekly intake (TWI) of cadmium was in 2009 reduced by EFSA from 7 to 2.5 µg /kg body weight (bw). The new TWI established was based on human studies on the dose-response relationship between concentration of cadmium in urine and kidney function. Severe cadmium-induced damage in cells in the proximal kidney tubules is considered to be irreversible and results in the progressive deterioration of renal function, even after cessation of exposure. Long-term exceedance of the TWI is of concern as it can increase the risk of developing kidney disease in the population. Keeping the exposure below the TWI will ensure that the cadmium concentrations in the kidneys will not reach a critical level for reduced kidney function.

Dietary intakes in Europe and Norway, and major dietary cadmium sources

In 2012, EFSA estimated that the mean cadmium exposure from food in Europe was close to the TWI and exceeded the TWI in some population groups, like toddlers and other children.

Previous exposure assessments in Europe and Scandinavia, including Norway, clearly show that cereal based food and root vegetables, particular potatoes, are the major dietary cadmium sources in the general population. These are, however, not the food groups with the highest cadmium concentrations. The highest concentrations have been found in offal, bivalve molluscs and crustaceans (e.g. crabs), and previous exposure assessments have shown that high consumption of such food can be associated with high cadmium exposure at the individual level. There is large variation at the individual level regarding consumption of particular food items (e.g. crab brown meat) that can be important contributors to cadmium exposure in addition to the exposure from the regular diet.

VKM has compiled the available Norwegian data on cadmium concentrations in food, mainly from 2006 and onwards. Comparison of Norwegian and European occurrence data shows that the cadmium concentrations for the food categories and items in the two datasets are within a similar range. The exceptions are fish filet and fish products (dishes based on minced fish meat), in which the mean cadmium concentrations were higher in products on the European market than in fish from Norway.

VKM has evaluated if there are national factors (geological factors, self-sufficiency rate, national occurrence data and food consumption habits) that would indicate that exposure in Norway is different from the rest of Europe. VKM has also evaluated available national and European data on concentrations of cadmium in blood and urine in relation to estimated dietary intakes.

VKM concludes that it can be expected that cadmium exposure among adults in Norway is within the range previously identified by EFSA, and close to the exposure estimated for Sweden. VKM is of the opinion that long-term cadmium exposure above the TWI as result from the regular diet in adults is unlikely in Norway, but that exceedance might occur from the additional consumption of food items with high cadmium concentrations, in particular brown meat of crabs. In dietary exposure estimates from EFSA, toddlers and other children have mean cadmium exposure exceeding the TWI, due to their higher food consumption relative to the body weight. Based on this, VKM expects that the mean dietary cadmium exposure in toddlers and children may exceed the TWI also in Norway.

Risk from cadmium intake from particular foods in Norway

Based on the mean concentrations of cadmium, VKM identified fish liver, bivalve molluscs and offal in addition to brown crab meat as particular food items that potentially can lead to added cadmium exposure in Norway.

Since these particular food items are mainly eaten on a seasonal or non-regular basis, it was stipulated that the associated cadmium exposure would come in addition to the mean exposure from regularly eaten food. In scenario exposure assessments, VKM calculated how much crabs/fish liver that could be consumed by adults and adolescents in addition to the regular diet without exceeding the TWI. The mean dietary exposures in adults and adolescents calculated by EFSA in 2012 were used as the mean exposures from regularly eaten food.

Since cadmium accumulates in the kidneys over time (decades), VKM is of the opinion that a short-term exceedance of the TWI (for some weeks or a few months) will not lead to adverse effects in the kidneys as long as the long-term exposure (for several months and years) is below the TWI. VKM therefore considers that the cadmium exposure from particular food items can be averaged over longer time-periods (for months and up to one year) than a week.

Crabs and fish liver: The edible crab *Cancer pagurus* is found all along the Norwegian coast up to Vesterålen, whereas further north the occurrence is infrequent. Brown meat from crabs contains much higher concentrations of cadmium than any other food item commonly consumed in Norway, and has approximately 14 to 20-fold higher concentration of cadmium than white crab meat. The cadmium concentration in fish liver is about two-fold higher than in white meat from crabs caught south of Saltenfjorden. A large part of the Norwegian adult population report consumption of crabs or fish liver at least a few times a year, while a small fraction consume these particular food items more frequently. Consumption of brown meat from crabs and fish liver is, however, not common in most European regions and therefore not covered by the exposure estimates performed by EFSA. The dietary assessment method used in the recent Norwegian national food consumption survey in adults (two times 24h dietary recall) does not supply reliable information about consumption of foods that are not eaten on a daily basis. In order to estimate cadmium exposure from rarely eaten foods, VKM has calculated scenarios for the exposure to cadmium from consumption of crabs and fish liver.

Scallops, oysters and offal: The cadmium concentrations in scallops and oysters are 2-3 fold higher than in white meat from crabs caught south of Saltenfjorden. Offal, in particular offal from game and sheep, contains much higher cadmium concentrations than the meat from the same species. However, consumption of offal, including offal from game, and bivalve molluscs is generally low in Norway, although high consumption in some population groups cannot be excluded. In contrast to Norway, consumption of offal and bivalve molluscs is more common in some European regions, and is therefore covered by the exposure estimates performed by EFSA.

Scenarios for cadmium exposure from crab or fish liver consumption

Crabs and filled crab shells: Because of high cadmium levels in edible crabs (Cancer pagurus) north of Saltenfjorden up to Vesterålen, Norwegian Food Safety Authority has issued advice to avoid consumption of all parts of crabs caught in this area. The scenarios presented below are valid only for meat of crabs caught south of Saltenfjorden.

Whole crabs contain a higher percentage of brown meat than commercially available filled crab shells, and this was taken into account in the scenarios.

Scenarios of cadmium exposure from crab consumption indicate that adults can eat approximately one whole crab or two filled crab shells per month in addition to regular food without exceeding the TWI. Averaged over a year, this corresponds to 13.5 whole crabs or approximately 25 filled crab shells. If adults only eat white crab meat, they can consume white meat from approximately nine crabs per week, which corresponds to white meat from approximately 468 crabs per year.

Adolescents can eat as little as approximately 0.3 whole crabs or 0.6 filled crab shells per month in addition to regular food without exceeding the TWI. Averaged over a year, this corresponds to 3-4 whole crabs per year or approximately 7 filled crab shells. If adolescents only eat white crab meat, they can consume white meat from about 2.5 crabs per week, which corresponds to white meat from approximately 129 crabs per year.

Since a higher crab consumption than the acceptable range calculated in the scenarios has been reported in Norwegian dietary surveys, VKM concludes that high consumers of crab brown meat are at high risk of exceeding the TWI. VKM concludes that cadmium exposure from white crab meat is not of concern in Norway.

Fish liver: The scenarios for fish liver consumption performed by VKM indicated that adults can in average consume 224 g saithe liver or 273 g cod liver from the North-Eastern Arctic Sea (Barents Sea) or 737 g cod liver from the North Sea per week in addition to regular food without exceeding the TWI. Because of their lower body weight, adolescents can consume less fish liver than adults in addition to regular food without exceeding the TWI. The scenarios indicated that adolescents can in average consume 60 g saithe liver or 73 g cod liver from the North-East Arctic Sea (Barents Sea) or 196 g cod liver from the North Sea per week in addition to regular food without exceeding the TWI.

The available Norwegian data on the consumption of fish liver indicate that such high fish liver consumption over a longer period (months and years) is unlikely, and consequently VKM concludes that cadmium exposure from fish liver consumption is not of concern in adults and adolescents.

Cadmium exposure from particular food items was not addressed for toddlers and children

Exposure scenarios were not calculated for children because there are no Norwegian data on the consumption of crabs or fish liver for toddlers and children. It was, however, anticipated by VKM based on common knowledge regarding children's food habits that crab brown meat and fish liver are rarely consumed by children. However, if consumed by children, crabs and fish liver would contribute more to the exposure in children than in adolescents and adults because of the low body weight in children and their high energy requirement relative to the body weight. Furthermore, they already have a mean cadmium exposure above the TWI from the regular diet as estimated by EFSA.

Uncertainties

VKM considers the uncertainties in the outcome of the present risk assessment as moderate. The highest uncertainty is associated with the amount of cadmium that can be allocated to particular food items, such as brown meat of crabs, before TWI is exceeded, since there is a high individual variation in cadmium exposure from regularly eaten food. The scenarios for exposure to cadmium from consumption of crabs and fish liver are VKM's best estimate for the maximum possible amounts of these particular food items that can be eaten without exceeding the TWI for cadmium.

Data gaps and recommendations

During the work with this risk assessment, VKM identified a need for updated consumption information for rarely consumed food in adults and children, as well as for more occurrence data on cadmium in food. There is a lack of information about cadmium levels in organically produced vegetables including those grown in alum shale areas. Furthermore, there is a need for systematic human biomonitoring studies (e.g. blood and urine) and Norwegian participation in European collaborative biomarker studies. A Total Diet Study would be helpful to reduce the uncertainty in the estimates of the mean dietary cadmium exposure in Norway.

Key words: VKM, risk assessment, cadmium, Cd, dietary, exposure scenario, crab consumption, fish liver consumption, Norwegian Scientific Committee for Food Safety

Sammendrag på norsk

Oppdrag fra Mattilsynet

Mattilsynet ba Vitenskapskomiteen for mattrygghet (VKM) å vurdere om nordmenn generelt eller grupper av befolkningen kunne forventes å ha forskjellig inntak av kadmium fra mat enn det som er rapportert for andre europeiske befolkningsgrupper. VKM ble videre bedt om å vurdere den potensielle helserisikoen knyttet til kadmiumeksponering fra brunmat i krabbe og til å identifisere hvor mye krabbe som kan spises av henholdsvis barn og voksne uten at det tolerable inntaket for kadmium overskrides. Til slutt ble VKM bedt om å identifisere andre spesielle matvarer som kan gi ekstra kadmiumeksponering i Norge. Mattilsynet vil bruke risikovurderingen som grunnlag for det norske bidraget i det pågående lovgivningsarbeidet i EU og til å vurdere om det er nødvendig å justere eksisterende nasjonale kostholdsrådene eller om nye må etableres.

Hvordan VKM har svart på bestillingen

VKM nedsatte en arbeidsgruppe som besto av medlemmer av Faggruppen for forurensninger, naturlige toksiner og medisinrester for å svare på bestillingen. Faggruppen har gjennomgått og revidert utkastet utarbeidet av arbeidsgruppen og har godkjent risikovurderingen av kadmiuminntak fra mat i den norske befolkningen.

Hva kadmium er og hvor giftig det for mennesker

Kadmium (Cd) er et tungmetall som forurenser miljøet. I tillegg til naturlig forekomst i berggrunnen er industri og landbruk forurensningskilder.

Mennesker eksponeres for kadmium fra mat, vann og luft. Mat er den viktigste kadmiumkilden hos ikke-røykere. Kadmium hoper seg spesielt opp i nyrene og i leveren. Mengden av kadmium i kroppen øker kontinuerlig i løpet av livet fram til cirka 60-70 års alderen, for så å flate ut. De best kjente giftvirkningene som følge av langvarig kadmium eksponering er påvist i nyrer og knokler.

Det tolerable ukentlige inntaket (TWI) av kadmium ble satt ned fra 7 til 2,5 µg/kg kroppsvekt av EFSA i 2009. Den nye TWI'en var basert på humane studier av dose-respons sammenheng mellom urinkonsentrasjon av kadmium og nyrefunksjon. Alvorlig kadmiumindusert skade på celler i proksimale nyretubuli anses å være irreversible og resulterer i tiltagende reduksjon av nyrefunksjonen, selv etter at eksponeringen opphører. Langvarig overskridelse av TWI er til bekymring fordi det kan øke risikoen for å utvikle nyresykdom i befolkningen. Hvis eksponeringen holdes under TWI vil det sikre at kadmiumkonsentrasjonen i nyrene ikke når det kritiske nivået som kan gi redusert nyrefunksjon.

Inntak fra mat i Europa og Norge, og hovedkilder for kadmium fra mat

EFSA anslo i 2012 at det gjennomsnittlige kadmiuminntaket fra mat i Europa var i nærheten av TWI, og oversteg TWI i enkelte befolkningsgrupper som barn 1-10 år.

Tidligere eksponeringsvurderinger i Europa og Skandinavia, inkludert i Norge, viser klart at kornbasert mat og rotgrønnsaker, særlig poteter, er de viktigste kadmiumkildene i den generelle befolkningen. Dette er imidlertid ikke matvaregruppene som har de høyeste konsentrasjonene av kadmium. De høyeste konsentrasjonene er funnet i innmat, skjell og krepsdyr (f.eks. krabbe). Tidligere eksponeringsvurderinger har vist at høyt inntak av slik spesiell mat kan knyttes til høy kadmiumeksponering hos enkeltindivider. Det er stor variasjon på individnivå med hensyn til inntak av spesielle matvarer (f.eks. brunmat fra krabbe) som kan være viktige bidragsytere til kadmiumeksponering i tillegg til det som kommer fra den vanlige kosten.

VKM har sammenstilt tilgjengelige norske data på kadmiumkonsentrasjoner i mat, hovedsakelig fra 2006 og utover. Sammenligning av norske og europeiske forekomstdata viser at kadmiumkonsentrasjoner for matvaregrupper og matvarer i de to datasettene er i samme størrelsesområde. Unntaket er fiskefilet og fiskeprodukter (matvarer med oppmalt fiskekjøtt), hvor den gjennomsnittlige konsentrasjonen av kadmium var høyere i produkter på det europeiske markedet enn i fisk fra Norge.

VKM har vurdert om det er nasjonale faktorer (geologiske faktorer, selvforsyningsgrad, nasjonale forekomstdata og kostvaner) som skulle tilsi at eksponering i Norge er ulik resten av Europa. VKM har også vurdert tilgjengelige nasjonale og europeiske data på konsentrasjoner av kadmium i blod og urin i forhold til estimerte inntak fra kosten.

VKM konkluderer med at kadmiumeksponering blant voksne i Norge er innenfor det som tidligere er identifisert av EFSA, og i nærheten av den eksponeringen som er beregnet for befolkningen i Sverige. VKM mener at langvarig kadmiumeksponering over TWI gjennom vanlig kost er usannsynlig hos voksne i Norge, men at overskridelse av TWI kan skje ved inntak av matvarer med høye kadmiumkonsentrasjoner, særlig brunmat av krabbe, i tillegg til den vanlige kosten. I inntaksberegninger gjort av EFSA overskrider gjennomsnittsinntaket av kadmium TWI hos barn 1-10 år, fordi barn har et stort matinntak i forhold til kroppsvekt. På bakgrunn av dette antar VKM at gjennomsnittsinntaket av kadmium fra kosten hos norske barn 1-10 år også kan overskride TWI.

Risiko fra kadmiuminntak av særskilte matvarer i Norge

Ut i fra gjennomsnittskonsentrasjoner av kadmium fant VKM at fiskelever, skjell og innmat, i tillegg til brunmat fra krabbe, er spesielle matvarer som potensielt kan bidra til ekstra kadmiumeksponering i Norge.

Slike spesielle matvarer blir hovedsakelig spist sesongmessig eller uregelmessig og kadmiumeksponeringen som dette medfører kommer i tillegg til gjennomsnittsinntaket fra vanlig kosthold. VKM har laget scenarier og beregnet hvor mye krabber/fiskelever som kan spises av voksne og ungdom i tillegg til den vanlige kosten uten å overskride TWI. Det gjennomsnittlige inntaket fra vanlig spist mat hos ungdom og voksne som EFSA beregnet i 2012 ble brukt som gjennomsnittsbidrag fra vanlig kost.

Siden kadmium hoper seg opp i nyrene over tid (flere tiår), mener VKM at en kortvarig overskridelse av TWI (i noen uker eller noen måneder) ikke vil føre til negative effekter på nyrene så fremt den langvarige eksponeringen (over flere måneder og år) er lavere enn TWI. VKM anser derfor at kadmiuminntaket fra spesielle matvarer kan midles over lengre tidsperioder (måneder og opp til ett år) enn en uke.

Krabber og fiskelever: Taskekrabbe (Cancer pagurus) finnes langs hele norskekysten opp til Vesterålen. Lenger nord er forekomsten sjelden. Brunt krabbekjøtt inneholder mye høyere konsentrasjon av kadmium enn noen annen matvare i Norge, og har ca. 14 til 20 ganger høyere konsentrasjon av kadmium enn hvitt krabbekjøtt. Kadmiumkonsentrasjonen i fiskelever er omtrent det dobbelte av det som finnes i hvitt kjøtt fra krabber fanget sør for Saltenfjorden. En stor andel av den voksne befolkningen i Norge har rapportert at de spiser krabber eller fiskelever minst et par ganger i året, mens en liten andel sier at de spiser slike spesielle matvarer hyppigere.

I de fleste områder i Europa er det imidlertid ikke vanlig å spise brunmat fra krabbe og fiskelever, og derfor er ikke slik mat inkludert i EFSAs inntaksberegninger. Metodene for å rapportere matinntak, som er brukt i den siste landsdekkende kostholdsundersøkelsen for voksne i Norge (rapportering av konsum to ganger 24-timer), gir ikke pålitelig informasjon om inntak av matvarer som ikke spises daglig. For å estimere kadmiumeksponering fra mat som spises sjelden, har VKM gjort scenarioberegninger av kadmiumeksponering fra krabber og fiskelever.

Kamskjell, østers og innmat: Kadmiumkonsentrasjonen i kamskjell og østers er 2-3 ganger høyere enn i hvitt kjøtt fra krabber fanget sør for Saltenfjorden. Innmat, særlig innmat fra vilt og sau, inneholder mye mer kadmium enn kjøtt fra samme art. Generelt sett spises det lite innmat, inkludert innmat fra vilt, og skjell i Norge, selv om høyt konsum i enkelte befolkningsgrupper ikke kan utelukkes. I motsetning til i Norge, er konsum av innmat og skjell mer vanlig i enkelte europeiske regioner og omfattes derfor av inntaksberegningene som EFSA har gjort.

Scenarier for kadmiuminntak fra krabber eller fiskelever

Krabber og fylte krabbeskjell: Mattilsynet fraråder konsum av krabber fanget nord for Saltenfjorden og opp til Vesterålen fordi de har høyt innhold av kadmium. Scenariene som presenteres nedenfor gjelder kun for krabber som er fanget sør for Saltenfjorden.

Hele krabber inneholder en høyere andel av brunmat enn fylte krabbeskall som er tilgjengelige i butikker. Dette ble det tatt hensyn til i scenariene.

Scenarier for kadmiumeksponering fra krabbe viser at voksne kan spise omtrent én hel krabbe eller to fylte krabbeskjell per måned i tillegg til vanlig mat uten å overskride TWI. Fordelt over ett år tilsvarer dette 13,5 hele krabber eller ca. 25 fylte krabbeskjell. Hvis voksne bare spiser hvitt krabbekjøtt, kan de spise hvitt kjøtt fra ca. ni krabber per uke, noe som tilsvarer ca. 468 krabber i året.

Ungdommer kan spise så lite som ca. 0,3 hele krabber eller 0,6 fylte krabbeskjell per måned i tillegg til vanlig mat uten å overskride TWI. Fordelt over ett år tilsvarer dette 3-4 hele krabber per år eller ca. 7 fylte krabbeskjell. Hvis ungdom bare spiser hvitt krabbekjøtt, kan de spise hvitt kjøtt fra ca. 2,5 krabber per uke, noe som tilsvarer hvitt kjøtt fra ca. 129 krabber i året.

Siden det i tidligere norske kostholdsundersøkelser har blitt rapportert konsum av flere krabber enn de maksimale antallene som ble funnet akseptabelt i scenariene, konkluderer VKM at høykonsumenter av brun krabbemat har høy risiko for overskridelse av TWI. VKM konkluderer at kadmiumeksponering fra hvitt krabbekjøtt ikke er til bekymring i Norge.

Fiskelever: Scenariene VKM har gjort for kadmiumeksponering fra fiskelever viser at voksne kan i snitt spise 224 g seilever eller 273 g torskelever fra Barentshavet eller 737 g torskelever fra Nordsjøen per uke, i tillegg til vanlig mat, uten å overskride TWI. På grunn av lavere kroppsvekt kan ungdom spise mindre fiskelever enn voksne i tillegg til vanlig mat uten å overskride TWI for kadmium. Scenariene viser at ungdom kan i snitt spise 60 g seilever eller 73 g torskelever fra Barentshavet, eller 196 g torskelever fra Nordsjøen per uke, i tillegg til vanlig mat, uten å overskride TWI.

Tilgjengelig informasjon om konsum av fiskelever i Norge tyder på at så høye inntak av fiskelever over lengre perioder (måneder og år) er usannsynlig, og derfor konkluderer VKM at kadmiumeksponering fra fiskelever ikke er til bekymring hos voksne og ungdom.

Kadmiumeksponering fra spesielle matvarer er ikke omtalt for barn 1-10 år

Det ble ikke gjort eksponeringsscenarier for barn fordi ingen nasjonale kostholdsundersøkelser har opplysninger om hvor mye krabber eller fiskelever disse gruppene spiser. Ut i fra kunnskap om barns matvaner vurderer VKM det slik at brunmat fra krabbe og fiskelever sjelden spises av barn. Dersom barn spiser slik mat, vil krabber og fiskelever bidra mer til eksponering hos barn enn hos ungdom og voksne på grunn av barnas lave kroppsvekt og høye energibehov i forhold til kroppsvekten. I tillegg har barn allerede et gjennomsnittlig kadmiuminntak fra vanlig kost som er høyere enn TWI slik EFSA har beregnet det.

Usikkerhet

VKM anser usikkerhetene i resultatene av denne risikovurdering som moderate. Den største usikkerheten er knyttet til hvor mye kadmium som kan settes av til spesielle matvarer som brunmat fra krabbe før TWI overskrides, siden det er en store individuelle variasjoner i kadmiuminntaket fra vanlig kost. Scenariene for kadmiumeksponering fra krabbe og fiskelever kan anses som VKMs beste estimat for den høyeste mengden av disse spesielle matvarene som kan spises uten å overskride TWI for kadmium.

Kunnskapsbehov og anbefalinger

Under arbeidet med risikovurderingen fant VKM at det er behov for oppdatert informasjon om konsum av mat som spises sjelden både hos voksne og barn, samt behov for mer data på forekomst av kadmium i mat. Det er mangel på informasjon om kadmiumnivået i økologisk produserte grønnsaker; inkludert de som blir dyrket i alunskiferområder. Videre er det behov for systematiske studier av konsentrasjon av kadmium i befolkningen (f.eks. blod og urin) og norsk deltakelse i europeiske samarbeidsstudier av biomarkører for kadmiumeksponering. En koststudie av type «Total Diet Study» ville være nyttig for å redusere usikkerheten i estimater for gjennomsnittlig kadmiumeksponeringen fra mat i Norge.

Nøkkelord: eksponeringsscenario, Cd, kadmium, konsum av fiskelever, konsum av krabbe, kosthold, risikovurdering, Vitenskapskomiteen for Mattrygghet, VKM

Abbreviations and glossary

Abbreviations

bw	body weight
BMDL	Benchmark dose level
BMI	body mass index
Cd	cadmium
CdS	cadmium sulfide (i.e. Greenockite)
CEN	European Committee for Standardization
Cu	copper
DNA	deoxyribonucleic acid
DMT1	divalent metal transporter 1
dw	dry weight
EFSA	European Food Safety Agency
FFQ	Food Frequencies Questionnaire
GFR	glomerular filtration rate
gm	geometric mean
GSH	glutathione
Hg	mercury
HUNT 2	Nord-Trøndelag Health Study (1995-97)
IARC	The International Agency for Research on Cancer
JECFA	Joint FAO/WHO Expert Committee on Food Additives
kDa	kilodalton
kg	kilogram
LB	lower bound
LOD	limit of detection
LOQ	limit of quantification
mg	milligram
ML	maximum level
MoBa	The Norwegian Mother and Child Cohort Study
MT	metallothionein
MW	molecule weight
NFG	The Norwegian Fish and Game study
Ni	nickel
NiCd	nickel/cadmium
NMKL	Nordisk metodikk komité
NOEL	no-observed-effect level
SSB	Statistics Norway (In Norwegian: Statistisk sentralbyrå)
TDS	total diet study
TWI	tolerable weekly intake
UNEP	United Nations Environment Programme

UB	upper bound
WHILA	Women's Health in the Lund Area, Sweden
WHO	World Health Organisation
ww	wet weight
Zn	zinc
ZnS	zinc sulphide
µg	microgram

Glossary

P95-exposure is the estimated exposure at the 95-percentile

Lower bound is when values below limit of detection (LOD) or limit of quantification (LOQ) are set to zero.

Maximum level (ML) The European Union (EU) is setting maximum levels for certain contaminants with a view to reducing their presence in foodstuffs to the lowest levels reasonably achievable by means of good manufacturing or agricultural practices. The objective is to achieve a high level of public health protection, especially for sensitive population groups, such as children or people with allergies (European Commission, 2006).

Provisional tolerable weekly intake (PTWI) is a term often used by the WHO, and reflects that tolerable intakes are provisional, since the database for setting a tolerable intake can be incomplete. Tolerable intakes can be changed if new studies indicate that the one already set is inappropriate.

Tolerable weekly intake (TWI) is the amount of a substance, or substance group, which can be consumed per week safely throughout a person's lifetime without appreciable risk of adverse health effects.

Upper bound is when values below limit of detection (LOD) or limit of quantification (LOQ) are set equal to the LOD or LOQ.

Background as provided by the Norwegian Food Safety Authority

Cadmium in sufficient quantities may cause kidney damage and carcinogenesis. In 2009, EFSA published a risk assessment of cadmium intake in the European population and established a new and lower value for the tolerable weekly intake (TWI) of 2.5 mg/kg body weight (bw). Norwegian consumption data were not included in the assessment. The average dietary intake of cadmium in the European population was calculated to be close to the newly established TWI, and special groups like vegetarians and children exceeded the TWI. This finding was confirmed by EFSA in 2012 through updated exposure calculations which showed that the average exposure for children and the 95-percentile exposure in adults may exceed the TWI for cadmium. Potatoes, bread, pastry, chocolate products, leafy vegetables, and molluscs contributed most to the cadmium intake. The highest cadmium concentrations were found in algae products, cocoa based products, shellfish, organ meats, mushrooms, seaweed, oilseeds and molluscs. Although severe kidney damage of cadmium is not likely to occur at the reported intake levels, EFSA was of the opinion that the overall dietary exposure to cadmium should be reduced. In 2010, JECFA derived a higher value for the tolerable intake than EFSA. Thus, in 2011 EFSA reassessed their cadmium assessment but concluded to maintain the TWI value of 2.5 mg/kg bw.

In EU, the maximum level (ML) for cadmium in crustaceans applies to the meat in legs, claws and tail (appendages and abdomen) only. Eating habits and traditions regarding which parts of crabs are considered edible vary greatly among European countries and regions. The Commission encourages Member States to provide national dietary advice based on regional eating patterns.

In Norway, it is common to eat most of the brown meat found in the shell. However, Norwegian authorities advise pregnant women, nursing mothers, women of childbearing age and children in Norway not to eat this type of meat. The advice is primarily based on the occurrence of dioxins and PCBs in crabs. In addition, cadmium contamination at certain places along the Norwegian coast line necessitates local consumption warnings not limited to particular population groups. Moreover, the Norwegian Food Safety Authority has also issued a general dietary advice to limit the consumption of sunflower seeds due to their potentially high concentrations of cadmium. Recent surveys show very high levels of cadmium in both brown and white meat from crabs caught in the northern parts of Norway.

The Norwegian Food Safety Authority requests a risk assessment of cadmium in order to take the necessary measures to prevent the Norwegian consumers to be exposed to hazardous amounts of cadmium through food. The risk assessment is intended to be a basis for the Norwegian contribution to the still ongoing legislative work in the EU, and to assess whether it is necessary to adjust the existing national dietary advices concerning cadmium and/or issue new ones.

Terms of reference as provided by the Norwegian Food Safety Authority

EFSA has lowered TWI for cadmium from 7 to 2.5 µg/kg bodyweight and calculated the exposure for the European population. Based on this, the Norwegian Food Safety Authority requests the Norwegian Scientific Committee for Food Safety to

- evaluate whether the Norwegian population or subgroups of the population have different food consumption patterns, which could lead to different dietary cadmium exposure than reported in other European population groups
- assess the potential health risk regarding consumption of crab brown meat,
- identify how much crab can be eaten at different levels of contamination – both by children and adults - without exceeding the TWI,
- identify specific foods or categories of food other than crab which would lead to an added cadmium exposure – both for the general population in Norway and specific groups.

Assessment

1 Introduction

Cadmium (Cd) is a heavy metal found as an environmental contaminant, both through natural occurrence and from industrial and agricultural sources. Cadmium is found in the environment mainly associated with zinc and to a lesser extent with lead and copper and is thus a by-product of the metallurgy of these elements. Cadmium has many technological applications, but it can be unintentionally released into the environment via the smelting of metals, the burning of fossil fuels, the incineration of waste materials, or the use of phosphate and sewage sludge fertilizers. Natural processes such as volcanic emissions and weathering of rocks can also contribute to cadmium contamination of the environment and subsequently of the food chain.

Food is the main source of cadmium exposure for the non-smoking general population. Increases in cadmium levels in soil result in an increase in the uptake of cadmium by plants, depending on plant species, pH and other characteristics of the soil. Furthermore, shellfish, crustaceans and mushrooms are natural accumulators of cadmium, and this is reflected in advice to restrict consumption in the general population or in particular groups of the population in Norway. The population in general is advised to avoid consumption of hepatopancreas in scallops and kidney from horse mussel because it may contain high level of cadmium (Matportalen, 2011a). Advice to restrict consumption of fish and/or shellfish is in addition given in some areas with known contamination of seafood (Matportalen, 2011c). In particular, because of high cadmium levels in edible crabs (Cancer pagurus) north of Saltenfjorden up to Vesterålen, there is a specific advice to avoid consumption of all parts of crabs caught in this area (Matportalen, 2011d). It is also a general advice to children, pregnant women and breast-feeding women to avoid consumption of crab brown meat, because it can contain high levels of contaminants like dioxins, PCBs and cadmium (Matportalen, 2015). The presence of cadmium in fish liver has up to now not been evaluated in the context of consumption warnings, but there is a general advice to avoid consumption of liver from cod caught by the coast, based on the high concentrations of dioxins and PCBs (Matportalen, 2011b).

The cadmium concentrations in edible crabs (Cancer pagurus) were investigated in a large survey, including a total of 475 individual crabs from 47 sites along the Norwegian coastline; from Hvaler in the south-east to Bø in Vesterålen in the north (NIFES, 2012b). The cadmium concentrations in both white and brown meat were substantially higher in crabs caught in northern Norway than in crabs caught in the south, with Saltenfjorden as a dividing line (NIFES, 2012b; Table A-5). The edible crab (Cancer pagurus) is infrequently found north of Vesterålen but is observed up to Finnmark (Institute of Marine Research, 2013).

Surveys conducted in the Salten area suggest that cadmium in crabs (Cancer pagurus) does not come from anthropogenic sources (Akvaplan-niva, 2012). The results suggest instead a natural process that allows crabs in this area to concentrate cadmium to a greater extent than elsewhere in the country; however, this process is so far unknown. The surveys do not suggest that there is more natural cadmium in bedrock in the Salten area than elsewhere in Norway. The high cadmium content in crabs from this area must therefore have other causes. In 2012, 157 sediment samples were collected from the area Støtt in the south, to Andholmen in the north. Generally low cadmium concentrations were found in the sediments (Akvaplan-niva, 2012).

Cadmium has no known physiological function in animals and humans but mimics other divalent metals that are essential for diverse biological functions. Cadmium is eliminated very slowly from the body, with a biological half-life of about 10-30 years. Cadmium is primarily toxic to the kidneys, especially to the proximal tubular cells, where it accumulates over time and may cause renal dysfunction. Cadmium can also cause bone demineralisation, either through direct bone damage or indirectly as a result of renal dysfunction (EFSA, 2009).

1.1 Cadmium risk assessment and tolerable intake

In 1988 the Joint FAO/WHO Expert Committee on Food Additives (JECFA) assessed the risks to human health related to the presence of cadmium in food and established a provisional tolerable weekly intake (PTWI) of 7 µg/kg body weight (bw) that was subsequently in 1995 endorsed by the Scientific Committee on Food (SCF, 1997); (JECFA, 1989). In 2009 the European Food Safety Authority (EFSA) established a tolerable weekly intake (TWI) of 2.5 µg/kg body weight (bw) for cadmium (EFSA, 2009). In 2010 the Joint FAO/WHO Expert Committee on Food Additives (JECFA) reviewed its previous evaluation on cadmium and established a provisional tolerable monthly intake (PTMI) of 25 µg/kg bw which corresponds to a weekly intake of 5.8 µg/kg bw (WHO, 2011). In compliance to a request from the European Commission the EFSA reviewed the approach taken in its assessment and carried out a comparison of the two evaluations on the basis of available information. This resulted in a reaffirmation of the previous conclusions (EFSA, 2011a).

The EFSA reported in 2009 that the current average dietary exposure to cadmium for adults in Europe is close to the TWI and that the exposure of some subgroups, such as children, vegetarians and people living in highly contaminated areas, could exceed the TWI. This was confirmed in 2012 in an exposure assessment based on updated cadmium occurrence data in food and extended consumption data (EFSA, 2012a). According to EFSA, the risk of adverse effects for an individual at the current dietary exposure is low because the TWI is not based on actual kidney damage, but on an early indicator of changes in kidney function, suggesting possible kidney damage later in life. However, EFSA concluded that there is a need to reduce exposure to cadmium at the population level.

1.2 Production, use and environmental fate

Cadmium is an element found naturally in minerals and soils and is transported with both water and air. The content varies in different minerals so that the concentration of cadmium will vary from area to area. Cadmium containing minerals are rare and contain low concentrations. Greenockite (CdS) is the only cadmium mineral of importance and it is almost always found together with zinc sulphide (ZnS). Cadmium is therefore mainly a by-product of zinc production. As a consequence of industrial activities, there are elevated levels of cadmium in sediments in some Norwegian fjords, such as the Sørfjord (local zinc production near the town of Odda), the Årdalsfjord and the Orkdalsfjord. For the Sørfjord, the Norwegian Food Safety Authority has issued a warning against the consumption of specific seafood items, partly because of cadmium.

Cadmium has been used e.g. in various industrial processes such as protecting steel against corrosion. Other applications have e.g. been in batteries, pigments, ceramic glaze and surface treatments but the element occurs also as a contaminant in other products, including some types of fertilizers. Cadmium occurs naturally in phosphate rock, and is thus present in phosphorus fertilizers in varying concentrations (Roberts, 2014). The Norwegian Food Safety Authority acknowledges that sources of cadmium to the food at present is atmospheric deposition, natural soil content, and addition through fertilizers/soil conditioners, and since the use of fertilizers/soil conditioners can be controlled, these are regulated. Mineral fertilizer containing phosphorus cannot contain more than 100 mg cadmium per kg phosphorous.

The proportion of cadmium consumed globally for nickel/cadmium (NiCd) battery production has increased, while the proportions for the other traditional applications of cadmium, more specifically coatings, pigments, and stabilizers, have decreased because of environmental and health concerns (U.S. Geological Survey, 2013).

The main share of industrially used cadmium comes from NiCd batteries and accounted for approximately 13 tons in Norway in 2007, i.e. 98 percent of the national usage. NiCd batteries are not produced in Norway, but are imported. At present, most NiCd batteries are replaced by other types of batteries, with the exception of applications in some power tools. The collection rate for NiCd batteries in 2009 was more than 100 percent of the imported quantities, due to the phasing out of small NiCd batteries from the market.

In 2007, the national emission of cadmium was estimated to 1.4 tons by the Norwegian Climate and Pollution Agency (now the Norwegian Environment Agency). Furthermore, it was estimated that additional 3.5 tons of cadmium reach Norway through atmospheric long-range transport. Closed mines are the most important known point sources for cadmium emissions into Norwegian waters. In 2009, the emissions from four abandoned mines were estimated to 0.26 tons. In the same year, emissions from 63 industrial plants amounted to a comparable quantity. Leaching from contaminated soil is another important source for cadmium emissions and was estimated to 0.4 tons in 2007.

Previously, VKM has recommended a survey on the concentrations of cadmium, copper and mercury in agricultural products derived from fields, where sewage sludge had repeatedly been applied (VKM, 2009). The levels of heavy metals in sewage sludge have been reported by Statistics Norway (SSB) since the early 1990s (Statistics Norway). For cadmium, lead, mercury and copper a decrease of 20-40% has been observed in the period 1993-2006. Calculations have shown that soils amended with the maximum allowed amount of sewage sludge (40 tons per hectare every 10th year) increase in their total concentrations of cadmium, mercury, zinc and copper 2-4 times during 100 years.

1.3 Specific factors that may influence cadmium concentrations in food in Norway

The contribution of atmospheric long-range transport to cadmium deposition in the environment has declined with 80-90% since the late 1970s until 2000, while recent changes are smaller (Steinnes et al., 2011). At some domestic sites, however, the deposition from local industries continues to be relevant, such as cadmium and zinc in Odda, and chromium and iron in Mo i Rana.

Alum shale: In specific areas of Norway, there are sizable natural deposits of the double sulphate mineral alum shale. The Norwegian alum shale is mostly black shale containing uranium and other elements and chemical compounds including cadmium. Since radioactive radon gas is a decay product of uranium, the Geological Survey of Norway (NGU) and the Norwegian Radiation Protection Agency (NRPA) have produced detailed maps depicting areas with alum shale. Accordingly, alum shale occurs mainly in the districts of Akershus, Oslo, Oppland, Buskerud and Hedmark. However, the maps show only the alum shale found as bedrock close to the surface, whereas alum shale is also found in deeper geological layers covered by other rock types. Preliminary tests by (Salbu et al., 2013) suggested that soil from areas in Hedmark with a high prevalence of alum shale contained elevated concentrations of a number of toxic heavy metals including cadmium. Vegetables grown on such soils, even if grown under organic farming conditions without mineral fertilizers, contained elevated cadmium concentrations. It was concluded that more thorough investigations are needed to provide information on the suitability for (organic) vegetable cultivation on alum shale soil.

In terms of farming methods, it is also known that low pH increases cadmium uptake by plants, thus liming will reduce cadmium bioavailability (Roberts, 2014). Adding organic matter to soils also influences cadmium bioavailability, since soils with higher organic matter have higher cation exchange capacity, which increases cadmium adsorption. Furthermore, soil pH and organic matter may interact in their effects on cadmium availability.

On the other hand, a systematic literature review and meta-analyses (Baranski et al., 2014) indicate that higher antioxidant concentrations and lower cadmium concentrations are linked to specific agronomic practices, such as non-use of mineral nitrogen and phosphorus fertilizers in organic farming.

In 1993-1996, the Norwegian Food Safety Authority conducted a survey on the prevalence of lead and cadmium in 19 types of potatoes and vegetables (Alne and Gjærstad, 1998). In addition to some samples of imported vegetables, samples of potatoes and vegetables collected from different regions of Norway according to the proportion of total production were analysed. The measured cadmium concentrations were generally low and within a similar range as results from Denmark and Sweden. Several samples of potatoes and carrots from regions with alum shale soil were included in the survey. Carrots from the Stange-Hamar area (alum shale area) showed in average a doubled cadmium concentration compared with non-alum shale area and two samples of potatoes contained more than 0.05 mg/kg cadmium. The survey showed that some samples of imported vegetables (origin not specified) had cadmium levels within a similar range as the Norwegian vegetables (Alne and Gjærstad, 1998).

Self-sufficiency rate: The self-sufficiency rate for food produced in Norwegian agriculture based on Norwegian feed has decreased to less than 40% during the last decade and is now historically low (Table 1.3-1; Norsk institutt for landbruksforskning, 2012).

Table 1.3-1 Per cent (%) self-sufficiency rates for food produced in Norwegian agriculture from 2000-2013 (Norsk institutt for landbruksforskning, 2014).

Year	Self-sufficiency rate (%) including fish	Food produced in Norwegian agriculture (%) (self-sufficiency rate excluding fish)	Food produced in Norwegian agriculture based on Norwegian feed (%)
2000	50	49	46
2001	50	50	46
2002	46	45	41
2003	50	50	45
2004	52	52	48
2005	53	52	48
2006	53	53	48
2007	53	52	46
2008	53	52	46
2009	48	48	43
2010	46	45	39
2011	48	47	41
2012	43	43	35
2013	46	45	37

There is, however, a great variability in self-sufficiency rates between different food categories (Figure 1.3-1) (Helsedirektoratet, 2013; Rolfsen, 2013). Milk and milk products, eggs and meat are almost completely from Norwegian production, whereas grains, vegetables and fruits are mainly imported. There are differences between types of vegetables and fruits as, for example, paprika is imported to practically 100% whereas carrots are about 80% of Norwegian origin (Landbruk, 2012). Although the total Norwegian grain production has increased with about 50% from 1961 to 2013 (Hoel et al., 2013) and the per-capita grain consumption has remained almost stable (Helsedirektoratet, 2015), the self-sufficiency rate for grain has decreased because the population has grown with 43%

from 1960 to 2014, and the trend is expected to continue (Statistics Norway, 2014). Thus, the future self-sufficiency rate for all food categories will possibly decrease even more.

About 70% of the food products imported to Norway are produced in EU countries (Rolfsen, 2013).

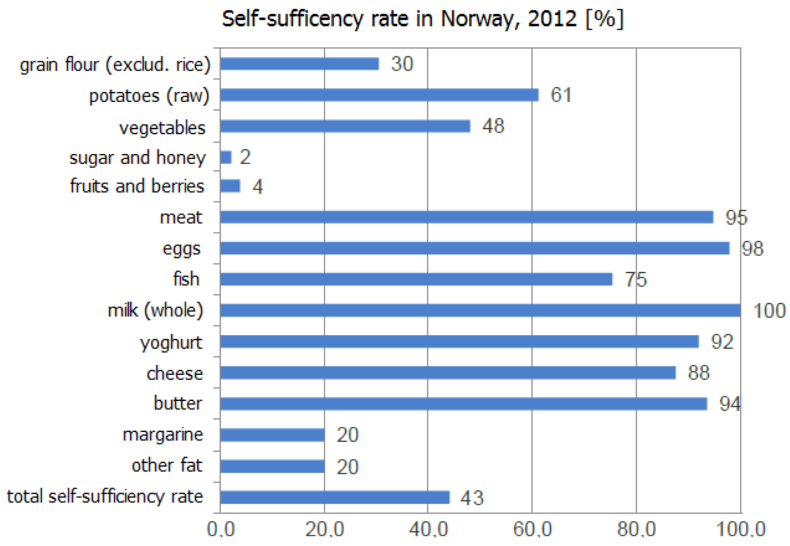

Figure 1.3-1 Self-sufficiency rate for major food categories in Norway in 2012 (Sources: Helsedirektoratet, 2013; Rolfsen, 2013)

1.4 Legislation

In 2014 the Regulation (EU) no 1881/2006 was amended with regard to maximum levels of cadmium in foodstuff (European Commission, 2014), see Table 1.4-1. However, for a number of foods that can contain relatively high levels of cadmium (e.g. game offal, fish liver, sun flower seeds, crab brown meat) no maximum levels have been set.

Table 1.4-1 Maximum levels of cadmium in foodstuff (European Commission, 2014)

Section no	Type of food	mg/kg wet weight
3.2.1	Vegetables and fruit, excluding root and tuber vegetables, leaf vegetables, fresh herbs, leafy brassica, stem vegetables, fungi and seaweed	0.050
3.2.2	Root and tuber vegetables (excluding celeriac, parsnips, salsify and horseradish), stem vegetables (excluding celery) ([27]). For potatoes the maximum level applies to peeled potatoes	0.10
3.2.3	Leaf vegetables, fresh herbs, celeriac and the following fungi: *Agaricus bisporus* (common mushroom), *Pleurotus ostreatus* (Oyster mushroom), *Lentinula edodes* (Shiitake mushroom)	0.20
3.2.4	Fungi, excluding those listed in point 3.2.3	1.0
3.2.5	Cereals excluding wheat and rice	0.10
3.2.6	• Wheat grains, rice grains • Wheat bran and wheat germ for direct consumption • Soy beans	0.20

Section no	Type of food	mg/kg wet weight
3.2.7	Specific cocoa and chocolate products as listed below:	
	• Milk chocolate with < 30% total dry cocoa solids	0.10[a]
	• Chocolate with < 50% total dry cocoa solids; milk chocolate with ≥ 30% total dry cocoa solids	0.30[a]
	• Chocolate with ≥ 50% total dry cocoa solids	0.80[a]
	• Cocoa powder sold to the final consumer or as an ingredient in sweetened cocoa powder sold to the final consumer (drinking chocolate)	0.60[a]
3.2.8	Meat (excluding offal) of bovine animals, sheep, pig and poultry	0.050
3.2.9	Horsemeat, excluding offal	0.20
3.2.10	Liver of bovine animals, sheep, pig, poultry and horse	0.50
3.2.11	Kidney of bovine animals, sheep, pig, poultry and horse	1.0
3.2.12	Muscle meat of fish, excluding species listed in points 3.2.13, 3.2.14 and 3.2.15	0.050
3.2.13	Muscle meat of the following fish: • Bichique (*Sicyopterus lagocephalus*) • Mackerel (*Scomber species*) • Tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*)	0.10
3.2.14	Muscle meat of the following fish: • Bullet tuna (*Auxis species*)	0.15
3.2.15	Muscle meat of the following fish: • Anchovy (*Engraulis species*) • Swordfish (*Xiphias gladius*) • Sardine (*Sardina pilchardus*)	0.25
3.2.16	Crustaceans, muscle meat from appendages and abdomen. In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) muscle meat from appendages	0.50
3.2.17	Bivalve molluscs	1.0
3.2.18	Cephalopods (without viscera)	1.0
3.2.19	Infant formulae and follow on-formulae:	
	• Powdered formulae manufactured from cows' milk proteins or protein hydrolysates	0.010[b]
	• Liquid formulae manufactured from cows' milk proteins or protein hydrolysates	0.005[b]
	• Powdered formulae manufactured from soya protein isolates, alone or in a mixture with cows' milk proteins	0.020[b]
	• Liquid formulae manufactured from soya protein isolates, alone or in a mixture with cows' milk proteins	0.010[b]
3.2.20	Processed cereal-based foods and baby foods for infants and young children	0.040[b]
3.2.21	Food supplements excluding food supplements listed in point 3.2.22	1.0
3.2.22	Food supplements consisting exclusively or mainly of dried seaweed, products derived from seaweed, or of dried bivalve molluscs	3.0

[a]as from 1 January 2019, [b]as from 1 January 2015

2 Hazard identification and characterisation

2.1 Literature

For studies on cadmium toxicity in humans, the search string (cadmium AND toxicity AND human) was used in PubMed, restricting to studies published after 2009 in order to find if there were major developments since the risk assessment from EFSA in 2009.

For studies on cadmium production, use and environmental fate, in addition to the search string "Cadmium, phosphorous, mineral, fertilizer" for searches in ISI web of science, information has been obtained through expert knowledge of literature produced for Norwegian environmental regulators.

Scientific articles describing the chemical properties of cadmium were retrieved from Google Scholar and PubMed by using the search strings (cadmium) AND ((chemistry) OR (characteristics) OR (physicochemical properties)). Furthermore, original articles were identified in reviews by (EFSA, 2009) and (United Nations Environmental Programme, 2010).

Comparably, articles describing the toxicokinetic parameters of cadmium were identified by using the search strings (cadmium) AND ((toxicokinetic) OR (absorption) OR (elimination AND half-life) OR (distribution AND organ) OR (metabolism AND in vivo OR in vitro) OR (phytate) OR (kidneys) OR (bones AND absorption) for literature searches in Google Scholar and PubMed. Furthermore, original articles were identified in reviews by EFSA, 2009; JECFA, 2010; United Nations Environmental Programme, 2010 and IARC, 2012; WHO, 2011.

For identification of biomonitoring studies which reported concentrations of cadmium in blood or urine we used the following search string in PubMed: (((urinary cadmium) OR blood cadmium) AND (Norway OR Sweden OR Denmark) AND biomonitoring). Relevant studies were read in full text, and additional studies were identified by hand search based on the basic search.

For identification of studies reporting estimated intake of cadmium we used the following search string in PubMed: ((cadmium exposure [Title/Abstract]) AND (diet OR FFQ)) AND (Norway OR Sweden OR Denmark). Additional studies were identified by hand search and by expert knowledge.

2.2 Chemistry

Cadmium (MW=112.4 g/mol) is a large, soft, heavy, ductile, and whitish metal, chemically similar to the two other stable metals in group 12 of the periodic table, zinc and mercury.

Cadmium is widely distributed in soils at relatively low levels but can be found in higher concentrations in sedimentary rocks and marine phosphates (European Commission, 2001).

Cadmium occurs naturally almost exclusively in the oxidation state +2 in inorganic salts such as the easily water-soluble $Cd(NO_3)_2$, $CdCl_2$, $CdSO_4$, and the hardly water-soluble $Cd(OH)_2$, $CdCO_3$, $Cd_3(PO4)_2$, CdS, and CdO (IARC, 2012). Solubility depends, however, on the pH of the solvent and is increased under acid conditions such as in the gastric juice or acidified soil. In contrast, at pH > 6 cadmium is adsorbed by the soil solid phase or is precipitated, and the concentrations of dissolved cadmium are greatly decreased (United Nations Environmental Programme, 2010). Salinity is of comparable importance as a high salt burden removes free Cd^{2+}-ions in favour of inert salt forms and reduces bioaccumulation (EFSA, 2009).

Phytate, the alkali salt of phytic acid (cyclic inositol hexakisphosphate), is the main storage form of phosphorus in plants, especially in seeds, nuts, and grains (Reddy et al., 1982). It can bind divalent cations in complexes, including essential minerals such as calcium (II), magnesium (II), zinc (II), copper (II), or iron (II) and harmful heavy metals such as lead (II) and cadmium (II). Cd^{2+} displaces Ca^{2+} from the phytate ligand. Phytate is indigestible for non-ruminants due to the lack of microbial phytase and can impair mineral absorption in the gastrointestinal tract (Hurrell, 2003). Food processing can partly break down phytate increasing the bioaccessibility of bound metals (e.g. in bread dough fermentation) (Lopez et al., 2001; Walker, 2004).

Cadmium can form organometallic compounds by binding to proteins and organic molecules or by complexing with organic anions. Under physiological conditions cadmium binds mainly to SH-groups in amino acids, low-molecular weight peptides, and metallothionein, a family of cysteine-rich proteins (Klaassen et al., 1999).

2.3 Toxicokinetics

Cadmium is a non-essential element for animal or plant life (United Nations Environmental Programme, 2010). Cadmium accumulates in plants (Simon et al., 1996) and animals, and subsequently in food (Croteau et al., 2005). Bioaccumulation factors in microorganisms and soil-living invertebrates are in the order of thousands (Selck et al., 1998), but less than 100 in higher organisms (Nordic Council of Ministers, 2003).

Humans are exposed to cadmium through food, air and water, not regarding extraordinary sources like medicinal implants or occupational exposure (Beckett et al., 2007). A review on cadmium toxicokinetics has been performed by the European Food Safety Authority (EFSA, 2009).

2.3.1 Absorption

The bioavailability of inhaled cadmium fumes (e.g. cadmium oxide in cigarette smoke) is in average 25-50% (up to 90%), and absorption from dust is 10-30%, depending on the particle size. There are large differences in blood cadmium levels between smokers and non-smokers illustrating the importance of respiratory uptake (EFSA, 2009). Absorption of cadmium through the skin is very low (0.5%). The average absorption of cadmium ions from food appear to vary considerably with age: Absorption rates have been estimated to be 3-5% based on kidney cadmium concentration data in 40-60 year old persons (Morgan and Sherlock, 1984). Cadmium urine data suggested gastrointestinal absorption rates of 5% and 10% in healthy young men and women, respectively (EFSA, 2009), but absorption rates of up to 20 to 40% have been determined in different studies. The absorption rates in 12-month old infants fed with ^{106}Cd-labelled wheat porridge have been found to vary between 4-37%, with an average of 18% (Crews et al., 2000). EFSA (2009) concluded that cadmium bioavailability in infants may be higher than the 5% average used for adult consumers.

Cadmium bioaccessibility and bioavailability vary considerably depending on the cadmium salt forms present, food ingredients (high fat, proteins), body status of micronutrients and essential elements, co-administration of drugs (e.g. disulfiram) or mineral supplements, age, and gender (Chan et al., 2007; Nelson et al., 2011). Organometallic complexes with glutathione or metallothionein, prevalent forms in shellfish, are less bioavailable than cadmium salts (Lind et al., 1995). Phytate-cadmium complexes are less absorbable than cadmium salts (Jackl et al., 1985), but can be broken down by food processing releasing the cadmium. Already small dietary deficiencies of calcium, iron, and zinc can strongly increase the bioavailability of cadmium from low-contaminated food (Reeves and Chaney, 2008). Women have generally a higher cadmium body burden than men because of their fluctuating body iron stores and lower plasma ferritin levels (Kippler et al., 2007; Bjermo et al., 2013).

Cadmium is absorbed in the duodenum and proximal jejunum mainly by transporter-facilitated transcellular transport. The divalent metal transporter 1 (DMT1) is the principle transport protein on the apical enterocyte membrane involved (Zalups and Ahmad, 2003), (Beckett et al., 2007; Vesey, 2010). The uptake is saturable (Andersen et al., 2004; Guirlet and Das, 2012).

2.3.2 Distribution

After absorption from the gut cadmium is bound by plasma proteins (albumin), transported via the portal vein to the liver, taken up by hepatocytes, bound to intracellular metallothionein, remobilized, and subsequently transported to the kidneys (Jin et al., 1998). The metallothionein-cadmium complex is filtered in the renal glomerulus, reabsorbed by receptor-mediated endocytosis into the proximal tubular cells (Vesey, 2010), and accumulated in the kidneys. More than half of the total cadmium body burden is deposited in the liver and kidneys (Akerstrom et al., 2013), about 30% in liver and 30% in the kidneys (Bernhoft, 2013). Kidney and liver concentrations are comparable after short-term exposure, but kidney concentrations are higher after long-term exposure (Bernard et al., 1990). Distribution rates increase dose-dependently in the liver, but not in the kidneys (Hiratsuka et al., 1999). Cadmium is found in practically all tissues but cannot penetrate the blood-brain barrier (Jin et al., 1998). It penetrates the blood-placenta barrier accumulating about 10-fold in the placenta (EFSA, 2009), but leakage from the placenta to the foetus is small. Cadmium concentrations in human milk are 5-10% of the maternal blood levels. Cadmium is taken up in the bone, especially during growth and remodelling (Ohta et al., 2002). Since cadmium disturbs both the intestinal uptake and the kidney-maintained homeostasis of calcium, the resulting bone demineralisation leads to further cadmium resorption. Women are more susceptible to cadmium induced bone loss due to the lower iron store and hormonal fluctuations, especially during pregnancy and menopause (Schutte et al., 2008). Urinary cadmium levels are directly correlated to decreases in bone density (Staessen et al., 1999).

Average kidney cadmium concentrations in humans are about zero at birth and increase almost linearly with age reaching a peak between ages 50 to 60, after which kidney concentrations decline. In liver, the end of linear increase is reached already by the age 20-25; the further increase is slower (EFSA, 2009). Typical peak values in the kidneys and liver are 40-50 mg/kg and 1-2 mg/kg wet weight, respectively. Urinary cadmium levels in healthy individuals with low-level cadmium exposure are strongly correlated to levels in kidney, especially after adjusting for creatinine and urinary albumin, and age (Akerstrom et al., 2013; Chaumont et al., 2013). Cadmium concentrations in infant urine correlate with levels in breast milk (Kippler et al., 2010).

2.3.3 Metabolism

Cadmium has a high affinity for the metal ion transport protein metallothionein, a 6.5 kDa protein with high cysteine content (Jin et al., 1998; Bertin and Averbeck, 2006), which can bind up to seven cadmium atoms per molecule. Cadmium induces the de-novo-synthesis of metallothionein in the liver (Nakagawa et al., 2004). After uptake into the proximal tubular cells of the kidneys the cadmium-metallothionein complexes are degraded in the lysosomes and free cadmium is released into the cytoplasm (Vesey, 2010), where it again is bound by metallothionein. Thus, the presence of cadmium in liver and kidneys is high due to the ability of these tissues to synthesize metallothionein.

2.3.4 Elimination

The cadmium turnover, including absorption, retention in the body, concentration in the blood, soft tissues and bone tissue, pool in internal organs, as well as faecal and urinary excretion, determines the total body burden. The cadmium body burden is negligible at birth and increases continuously during life until approximately the age of about 60-70 years, from which it levels off or even decreases. Cadmium is eliminated very slowly with daily losses of 0.007 and 0.009% of the total body burden in urine and faeces via the bile, respectively (EFSA, 2009). The urinary excretion depends on blood and kidney concentrations and corresponds approximately to the daily intake at steady state. Clearance in milk is low

(Houpert et al., 1997). Inhaled particle-bound cadmium is mostly transported directly to the gut via mucociliary clearance and excreted (EFSA, 2009). Furthermore, cadmium at low concentrations is measurable in exhaled breath condensate from ex-smokers for many years after smoking cessation illustrating that a considerable fraction of the cadmium deposits in the lungs is cleared by exhalation (Mutti et al., 2006).

The biological half-life of cadmium in healthy humans is about 10 to 30 years (EFSA, 2009), but is shortened in persons with renal damage. Regarding the individual organs, half-life is 6 to 38 years in human kidneys and 4 to 19 years in the liver (EFSA, 2009). The initial half-life in blood is three to four months, reflecting mainly deposition into the organs and not elimination from the body (Bernhoft, 2013), whereas the terminal half-life in blood is about eleven years and depends on the body burden (Amzal et al., 2009).

2.4 Toxicity in humans

2.4.1 Acute effects

Consumption of food that is highly contaminated with cadmium leads to acute gastrointestinal symptoms, such as nausea, vomiting, and diarrhoea, which as a consequence reduces the cadmium absorption (EFSA, 2009; Thevenod and Lee, 2013). Since the cadmium uptake in the intestine is saturable (divalent metal transporter 1 (DMT1)), a high short-term intake might not be a problem and does not lead to concentration peaks in blood (Chapter 2.3.1). For low level chronic dietary cadmium exposure acute effects are not relevant.

2.4.2 Chronic effects

The most well characterised chronic toxicities resulting from cadmium exposure are effects on kidneys and bones. Long-term cadmium exposure causes the so called itai-itai ("ouch-ouch") disease, which was first reported from the Jinzu river basin in Japan, where the population was exposed to high cadmium levels from rice irrigated with contaminated water. The painful disease is characterized by multiple skeletal fractures and with a mixed pattern of osteomalacia and osteoporosis in combination with kidney damage. The association between cadmium exposure and osteoporosis and increased risk of bone fractures has later been shown in several studies. This effect has been seen at very low levels of cadmium exposure, and recent studies indicate that this might occur at slightly lower exposure than what is associated with kidney disease, supporting the lower TWI set by EFSA in 2009 than the one set by WHO in 2010 (reviewed by Akesson et al., 2014).

Cadmium may induce bone effects both by a direct effect on the bone tissue or indirectly via cadmium induced renal damage. Effects that can be secondary to tubular damage can be deficient reabsorption of calcium and compromised activation of vitamin D in the renal cortex. However, in experimental animals, also effects on bone mineralisation without effects on the kidneys have been reported, and there are several indications of direct effects of cadmium on bone. Therefore, an increase in urinary calcium after low level cadmium exposure can also be the result of increased bone demineralization (EFSA, 2009; Akesson et al., 2014).

The kidney is the most sensitive target organ for low level chronic dietary exposure to cadmium. The accumulation of cadmium in cells in the proximal tubules leads to cell dysfunction and cell damage. This leads to decreased tubular reabsorption and therefore increased excretion of low molecular weight proteins as well as increased excretion of markers of cell shedding. The urinary increased level of e.g. beta 2 microglobulin, retinol binding protein, alpha-1-microglobulin and membrane bound b-isozyme of N-acetyl-beta-glucosaminidase are early signs of kidney damage after cadmium exposure. Furthermore, the urinary excretion of high molecular weight proteins and the glomerular filtration rate (GFR) reflect the efficacy and rate of renal ultrafiltration of the blood. Any deviation of GFR from the normal range may indicate renal damage. Severe cadmium-induced tubular damage is considered to be irreversible and results in the progressive deterioration of renal function, even after cessation of exposure (EFSA, 2009).

Cadmium coupled to metallothionein is filtered through the renal glomeruli and then reabsorbed by proximal tubular cells, in which the Cd-MT is degraded to Cd^{2+} (see Chapter 2.3). The tubular cells synthesise MT in order to neutralise the free Cd^{2+}. At a critical concentration, the tubular cells are no longer able to synthesise enough metallothionein so that the level of free intracellular Cd^{2+} increases and damages the tubular cells. This result in the leaking of enzymes and low molecular weight proteins, as well as the increased excretion of cadmium, either bound to metallothionein or probably also as free Cd^{2+}-ions.

Cancer is another chronic effect associated with cadmium exposure and The International Agency for Research on Cancer (IARC) has classified cadmium as a human carcinogen (Group 1) on the basis of occupational studies. Cadmium does not interact directly with deoxyribonucleic acid (DNA), but is considered genotoxic due to the induction of oxidative stress and inhibition of DNA repair. Studies on non-occupational human exposure to cadmium have found associations with increased risk of cancer in lung, endometrium, bladder, and breast (EFSA, 2009; Akesson et al., 2014).

2.4.3 Background for the TWI set by EFSA in 2009

The TWI of 2.5 μg/kg bw established by EFSA in 2009 was based on a meta-analysis of numerous human studies of the dose-response relationship between urinary cadmium/g creatinine and urinary beta-2-microglobulin (EFSA, 2009). Both are considered as good biomarkers of tubular damage, which has been confirmed in a large number of studies. EFSA (2009) also explored the possibility to base a tolerable intake on osteoporosis or increased risk of bone fractures. However, they concluded that the available studies were fewer than for kidney effects and that the existing studies were largely heterogeneous. The range of urinary cadmium in the studies on possible effects of cadmium on bone was starting from 0.5 μg/g creatinine, quite similar to the levels in studies on kidney damage. Regarding effects on cancer development EFSA considered the dose-response data as insufficient for a quantitative risk assessment.

Based on the data on increase in urinary beta-2-microglobulin, a group-based $BMDL_{05}$ of 4 µg urinary Cd/g creatinine was derived. A chemical specific adjustment factor of 3.9 was applied to account for human variability in urinary cadmium within each dose-subgroup in the analysis. This resulted in a reference point of 1.0 µg cadmium/g creatinine in urine. In order to calculate the dietary cadmium intake that would not lead to higher urinary cadmium than 1.0 µg cadmium/g creatinine, information from a large set of non-smoking Swedish women was used (Amzal et al., 2009). It was calculated that at age 50, 95% of the women would have urinary cadmium concentrations below the reference point of 1 µg cadmium/g creatinine if the average daily dietary cadmium intake does not exceed 0.36 µg Cd/kg bw. Considering the cumulative effects of cadmium, exposure was expressed as a weekly dietary intake of 2.5 µg cadmium/kg bw. No additional adjustment or uncertainty factor in order to account for individual variability in susceptibility was considered to be necessary, because the data used in the modelling related to an early biological response and in a sensitive population.

2.4.4 Biomonitoring studies in Norway and Europe

Cadmium exposure reflecting the internal dose is monitored either in urine or blood. As cadmium is accumulated in the kidney and has a long half-life, the urinary excretion corresponds approximately to the daily intake at steady state, which is obtained after long-term exposure (Akerstrom et al., 2013). Ideally, urinary cadmium is assessed as the amount excreted over 24 hours or if this is not available, a spot urine sample corrected for creatinine concentration. Blood cadmium reflects short-term exposure over the past three to four months (Lauwerys et al., 1994; Bernhoft, 2013; Akesson et al., 2014), and is usually assessed in whole blood (EFSA, 2009). Tobacco smoking substantially increases cadmium exposure and, thereby, both blood and urinary cadmium concentrations (Akesson et al., 2014).

2.4.4.1 Levels in blood and urine in Norway and Europe

An overview of biomonitoring data on cadmium exposure reported in population studies in Norway and countries relevant for comparison with Norwegian data is shown in Table 2.4.4.1-1 and described below.

Table 2.4.4.1-1 Overview of population studies which include biomonitoring data on cadmium (Cd) exposure

Country and Study	Year	Participants	Urinary Cd median (5th, 95th percentile)	Blood Cd median (5th, 95th percentile)
Norway The Norwegian Fish and Game study (NFG)[a]	2003-2004	81 men and 98 women age 28-76 y	All: 0.18 (0.04, 0.69) µg/L *Creatinine adjusted:* 0.16 (0.03, 0.62) µg/g [0.14 in men and 0.20 µg/g in women] Non-smokers: 0.11 µg/g Former smokers: 0.18 µg/g Present smokers: 0.26 µg/g	All: 0.45 (0.11. 1.18) µg/L Non-smokers: 0.30 µg/L Former smokers: 0.44 µg/L Daily or occasional smokers: 1.20 µg/L
Norway Sub-study; Norwegian Mother and Child Cohort Study (MoBa val)[b]	2003-2004	119 pregnant women age 23-44 y	Non-smokers: 0.22 (0.11, 0.79) µg/L Smokers: 0.45 (0.34, 2.6) µg/L	Non-smokers: 0.12 (0.07, 0.27) µg/L Smokers: 0.47 (0.30, 0.84) µg/L
Norway Nord-Trøndelag Health Study (HUNT 2)[c]	1995-1997	448 non-smoking women age 20-55 y	-	0.37 ± 0.25[†] 0.26 ± 0.16[††]
Sweden Riksmaten[d]	2010-2011	128 men (mean age 52 y) and 145 women (mean age 48 y)	*Creatinine adjusted:* All: 0.16 (0.04, 0.63) µg/g Men: 0.12 (0.04, 0.48) µg/g Women: 0.22 (0.09, 1.2) µg/g	All: 0.19 (0.09, 1.1) µg/L Men: 0.17 (0.08, 0.85) µg/L Women: 0.22 (0.09, 1.2) µg/L
The Swedish Mammography Cohort[e]	2004-2007	2688 women (56 to 69 y), of which 1225 never-smokers	*Creatinine adjusted*: All: 0.34 (0.15, 0.79) µg/g Non-smokers: 0.29 (0.14, 0.64) µg/g.	-
Sub-study in the Swedish Mammography Cohort [f]	2004-2007	680 women (56-70 y) who had never smoked	*Creatinine adjusted:* All 0.31 µg/g [range: 0.09, 1.23]	-
Sweden The Women's Health in the Lund Area (WHILA) [g]	1999-2000	804 women age 53-64 y	All: 0.52 (0.24, 1.3) µg/L Non-smokers: 0.45 µg/L *Creatinine adjusted:* 0.67 µg/g	0.38 (0.16, 1.8) µg/L Non-smokers: 0.30 µg/L Smokers: 11.1 µg/L
Sweden Pregnant women in Stockholm area [h]	1994-1996	216 pregnant, non-smoking age 20-45 y	Non-smokers: 0.31 (0.11, 1.1) µg/L[§]	0.16 (<LOD, 0.73) µg/L [§]
Biomonitoring study of women and children in 16 European countries [i,j]	2011-2012	[j]1685 women (24-52 y) and 1689 children (5-12 y) [i]1632 women (24–52 y), and 1689 children (5–12 y)	0.22 (0.21, 0.23) µg/L in mothers (all) and 0.071 (0.069, 0.074) in children *Creatinine adjusted[§§]:* Non-smoking mothers (n=1272): 0.18 µg/g Smokers (360): 0.24 µg/g Children: 0.065 µg/g	-
Denmark [k]	2011	143 mothers (31-52 y) and 123 children (6-11 y)	0.021 µg/L in children (range: <LOD to 0.27 µg/L) and 0.115 µg/L in mothers (range <LOD to 1.09 µg/L).	-

[a]Birgisdottir et al., 2013, [b]unpublished data from study described by Brantsaeter et al., 2008, [c]Meltzer et al., 2010, [d]Bjermo et al., 2013, [e]Engstrom et al., 2011, [f]Amzal et al., 2009, [g]Akesson et al., 2006, [h]Akesson et al., 2002, [i]Berglund et al., 2014, [j]Den Hond et al., 2015, [k]Morck et al., 2014.
[†]Values in women with serum ferritin <12 µg/L, values represent mean ± SD,
[††]Values in women with serum ferritin ≥12 µg/L, values represent mean ± SD, [§]Values represent median and range, [§§]Values represent geometric means, y – year, LOD – limit of detection.

The Norwegian Fish and Game study: The Norwegian Fish and Game study is a population-based study. The aim of the study was to obtain information about dietary intake and exposure to environmental contaminants. The study was performed in three parts as described in Chapter 3.2. Part C of the study was conducted in 2003-2004. The participants donated spot urine and blood samples and answered a validated food frequency questionnaire (FFQ) assessing the average intake of all food consumed over the last 12 months (Birgisdottir et al., 2013). Cadmium concentrations measured in spot urine and full blood samples were available for n=179 (98 men and 81 women). The median urinary cadmium concentration in the whole group was 0.18 (0.04, 0.69) µg/L [corrected for creatinine: 0.16 (0.03, 0.62) µg/g creatinine] and the median (5- and 95-percentile) whole-blood cadmium was 0.45 µg/L (0.11, 1.8 µg/L). Cadmium concentrations in urine as well as in blood were significantly higher in smokers than in non-smokers (Table 2.4.4.1-1). Only one participant (0.7%) exceeded the $BMDL_{01}$ for increased risk of kidney toxicity of 1 µg cadmium/g creatinine (EFSA, 2009). In non-smokers, total seafood intake was the only dietary variable significantly associated with higher urinary cadmium, and the association was driven by crab consumption. Consumption of offal from game was associated with non-significant higher cadmium concentration in urine (few consumers).

The Norwegian Mother and Child Cohort Validation study (MoBa Val): Cadmium concentrations in blood and urine were measured in 119 pregnant women participating in a sub-study (2003-2004) of the Norwegian Mother and Child Cohort. The aim of the sub-study was to validate a new food frequency questionnaire. The study population comprised 119 pregnant women who in addition to providing detailed dietary information also collected 24-h urine samples and donated blood for biomarker studies (Brantsaeter et al., 2008). In non-smokers the median (5- and 95–percentile in brackets) cadmium concentrations were 0.22 (0.11, 0.79) µg/L in urine and 0.12 (0.07, 0.27) µg/L in blood. As in other studies, higher values were seen in smokers than in non-smokers (Table 2.4.4.1-1).

The Norwegian HUNT 2 study: Blood cadmium was measured in 448 healthy, menstruating non-smoking women participating in HUNT 2 (1995-1997). The aim of the study was to examine the relationship between iron status and blood concentration of divalent metals including cadmium (Meltzer et al., 2010). The study population was stratified for serum ferritin, with 257 women classified as iron-depleted (serum ferritin<12 µg/L) and 119 as iron-repleted (serum ferritin≥12 µg/L). Significantly higher blood cadmium concentrations were observed in iron-depleted than in iron-repleted women (Table 2.4.4.1-1).

Riksmaten, a substudy within the Swedish national food survey: A Swedish study examined the body burden of cadmium and other metals in blood among Swedish adults in a subgroup (n=273) of the national dietary survey Riksmaten 2010-2011 (Bjermo et al., 2013). The subgroup participants had submitted dietary data (FFQ and 4-d food diary) and also donated urine and blood samples. The median (5- and 95-percentile in brackets) cadmium concentrations were 0.16 (0.04, 0.63) µg/g creatinine in urine and 0.19 (0.09, 1.1) µg/L in blood (Table 2.4.4.1-1). Urinary and blood cadmium levels were higher in smokers than in non-smokers, higher in women than in men, and increased with age. Blood cadmium increased with decreasing levels of plasma ferritin. Food intake data were thoroughly examined as predictors of urinary and blood cadmium levels. A number of food items were associated with urinary and blood cadmium levels in the crude analyses, but when adjusting for age, gender, education, smoking, and plasma ferritin, only meat consumption was associated in an inverse manner with cadmium levels both in urine and blood. Cadmium levels in urine and blood were independent of drinking water source, i.e. water well or municipal water supply system. When smokers were excluded, the association between cadmium levels, personal characteristics and diet remained the same.

The Swedish Mammography Cohort: Within the population-based Swedish Mammography Cohort, urinary cadmium concentrations were assessed in 2688 women (56 to 69 years) and examined in relation to bone mineral density (Engstrom et al., 2011). The median urinary cadmium concentration was 0.34 (5- to 95-percentile 0.15 to 0.79) µg/g of creatinine in all women and 0.29 (0.14 to 0.64) µg/g of creatinine in women who never smoked (Table 2.4.4.1-1).

The Swedish Mammography Cohort - validation study: Between 2004 and 2007, a total of 1519 women were recruited to a validation study within the Swedish Mammography Cohort (Amzal et al., 2009). After excluding those with implausible values for total energy intake and women who had ever smoked, urinary cadmium data for 680 women (56–70 years of age) were included in a study that modelled dietary cadmium exposure based on urinary cadmium concentrations and this was used by EFSA when setting the TWI (see Chapter 2.4.3). Urinary cadmium concentration was determined in the first-void morning urine. The median creatinine adjusted cadmium concentration was 0.31 µg/g, with a range from 0.09 to 1.23 µg/g (Table 2.4.4.1-1). The study assessed individual data on dietary intake and evaluated the variability in cadmium kinetics.

The Women's Health in the Lund Area, Sweden (WHILA): Cadmium in blood and urine was measured in a population-based survey in 820 women (53–64 years of age) in southern Sweden [Women's Health in the Lund Area (WHILA)], an area with no known historical cadmium contamination (Akesson et al., 2006). The aim of the study was to investigate cadmium-related effects on bone. Median urinary cadmium was 0.52 µg/L adjusted to a mean density of 1.015 g/mL, and was higher in smokers than in never-smokers (0.76 vs 0.45 µg/L) (Table 2.4.4.1-1). The median value for creatinine adjusted urinary cadmium was 0.67 µg/g creatinine, which is higher than in other studies in Sweden. The authors used density adjusted rather than creatinine adjusted cadmium values for their analysis of cadmium and bone-related variables because creatinine values depend on muscle mass and is affected by age and physical fitness, which are also predictors of bone status.

Pregnant women in Stockholm area (Sweden): A prospective study measured iron status and cadmium concentration in urine, blood, and placenta in 216 non-smoking women during 2 year-monitoring study with start in early pregnancy (Akesson et al., 2002). Median cadmium concentrations in early gestation were 0.31 µg/L (0.11 to 1.1 µg/L) in urine and

0.16 µg/L (range: below limit of detection to 0.73 µg/L) in blood (Table 2.4.4.1-1). This was the first study to show a persistent effect of low iron status on body burden of cadmium, as reflected in urinary cadmium concentrations. Urinary cadmium increased longitudinally in women with exhausted iron stores during their pregnancy. The increase in urinary cadmium with age was more pronounced in parous than in nulliparous women.

Biomonitoring study of women and children in 16 European countries (Democophes): The pan-European human biomonitoring project (Democophes) performed harmonized measurements of cadmium in urine in a comparable way in mother-child couples throughout Europe. The countries included were: Sweden, Denmark, UK, Ireland, Switzerland, Luxemburg, Germany, Belgium, Spain, Portugal, Poland, Slovenia, Slovak Republic, Czech Republic, Hungary, Cyprus and Romania. Berglund et al. (2014) evaluated the overall cadmium exposure and significant determinants of cadmium exposure. The study population comprised 1632 women (24-52 years of age), and 1689 children (5-12 years of age) from 32 rural and urban areas. Participants were recruited within a core period of 6 months in 2011-2012. Women were stratified as smokers and non-smokers. As expected, smoking mothers had higher geometric mean (gm) urinary cadmium (0.24 µg/g creatinine; n=360) than non-smoking mothers (gm 0.18 µg/g creatinine; n=1272; $p<0.0001$), and children had lower levels (gm 0.065 µg/g creatinine; n=1689) than their mothers at the country level (Table 2.4.4.1-1). Factors associated with or tending to be associated with higher urinary cadmium in mothers as well as children were lower maternal education and living in a rural area compared to living in an urban area. Poland had the highest cadmium levels of the 16 countries both with regard to smoking and non-smoking women, while Denmark had the lowest. The authors concluded that it is not clear whether differences between countries are related to differences in the degree of environmental cadmium contamination or to differences in lifestyle, socioeconomic status or dietary patterns.

Den Hond et al. (2015) also presented urinary cadmium concentrations in Democophes, but in a slightly larger sample (1685 mothers and 1698 children) than in Berglund et al. (2014) and with cadmium concentrations presented as geometric means and 95% confidence intervals not adjusted for creatinine. Smoking and non-smoking women were treated as one group. As in the Berglund et al. (2014) study, mothers in Poland had the highest and those in Denmark the lowest cadmium levels. The median cadmium concentrations for all countries combined were 0.22 µg/L in mothers and 0.071 µg/L in children (Table 2.4.4.1-1). The authors included a comparison with the corresponding cadmium concentrations in the US National Health and Nutrition Examination Survey IV sampled in 2009-2010, with geometric mean of 0.19 µg/L in mothers (n=1450) and of 0.057 µg/L in the children (n=415).

The Danish contribution to the European biomonitoring study Democophes: The Danish contribution to the European biomonitoring study Democohpes was published by Mørck et al. (2014) in addition to the Danish results being part of the overall results presented by Berglund et al. (2014). The study sample comprised 143 mothers (31-52 years) and 123 children (6-11 years). The geometric mean urinary cadmium was 0.021 µg/L in children (range: <LOD to 0.27 µg /L) and 0.115 µg/L in mothers (range: <LOD to

1.09 µg/L). The corresponding geometric means when adjusting for creatinine were 0.22 and 0.118 µg/g creatinine, respectively (Table 2.4.4.1-1). There was no correlation between the cadmium levels of mothers and children. There was a significant correlation between urinary cadmium and urinary cotinine (marker of tobacco exposure) in mothers as well as in children. In mothers, cadmium increased with age and body mass index (BMI) and decreased with meat intake. In children, cadmium was inversely correlated with cereal consumption, which, according to the authors was the opposite of what was expected. A non-significant increase was indicated for increasing rice consumption. As in the main study (Berglund et al., 2014) higher cadmium was found in those residing in rural areas than in urban areas. Mørck et al. (2014) found no clear source of this difference. Berglund et al. (2014) state that the differences in urinary cadmium levels between rural and urban areas could not be explained by factors related to rural living such as using a private well for drinking water. They suggest that children in rural areas could be exposed to cadmium through soil, dust or use of cadmium-containing fertilizers, which was not covered by the questionnaire.

2.4.4.2 Norwegian biomonitoring data in comparison with other countries

The studies summarised above show that Sweden stands out with a large number of studies reporting cadmium levels in urine and blood. In general, cadmium exposure in Sweden and neighbouring countries including Norway is low (Table 2.4.4.1-1). Reported median urinary cadmium (creatinine adjusted) values in studies from Sweden ranged from 0.16 µg/g (0.12 in men and 0.22 µg/g in women) in the national dietary survey Riksmaten (Bjermo et al., 2013) and up to 0.67 µg/g in postmenopausal women in the WHILA study (Akesson et al., 2006). For comparison, median creatinine adjusted urinary cadmium in the Norwegian Fish and Game study was 0.16 µg/g in men and 0.20 µg/g in women, and 0.11 µg/g in non-smokers, 0.18 µg/g in former smokers and 0.26 µg/g in smokers (Birgisdottir et al., 2013).

In pregnant non-smoking women, median urinary cadmium concentration (not creatinine adjusted) was 0.31 µg/L in Sweden (n=216) (Akesson et al., 2002) and 0.22 µg/L in Norway (n=119) (Table 2.4.4.1-1).

As for urinary cadmium, reported concentrations of blood cadmium are also comparable between Norway and Sweden. Median blood cadmium was 0.30 µg/L in non-smokers in the Norwegian Fish and Game study (Birgisdottir et al., 2013) and also 0.30 µg/L in postmenopausal women in the WHILA study (Akesson et al., 2006). Blood cadmium in postmenopausal women in Norway was reported as means according to iron status, and values were in the same range [0.37 in iron-depleted and 0.26 µg/L in iron-repleted women]. Median blood concentrations in non-smoking pregnant women in Norway and Sweden were 0.12 and 0.16 µg/L, respectively (Table 2.4.4.1-1). Hence, cadmium exposure is comparable in Norway and Sweden also for studies reporting the short term biomarker.

Comparison between studies and countries is challenging because of differences in age and lifestyle and because cadmium concentrations can be reported in different ways.

Consequently, the comparison between countries in the European biomonitoring study Democophes is particularly valuable for comparison of women in the age range 24-52 years and children in the age range 5-12 years because the study succeeded in performing harmonized biomarker measurements in all participating countries. The results showed that Denmark and Sweden were among the countries with the lowest cadmium exposure in mothers and children (Figure 2.4.4.2-1).

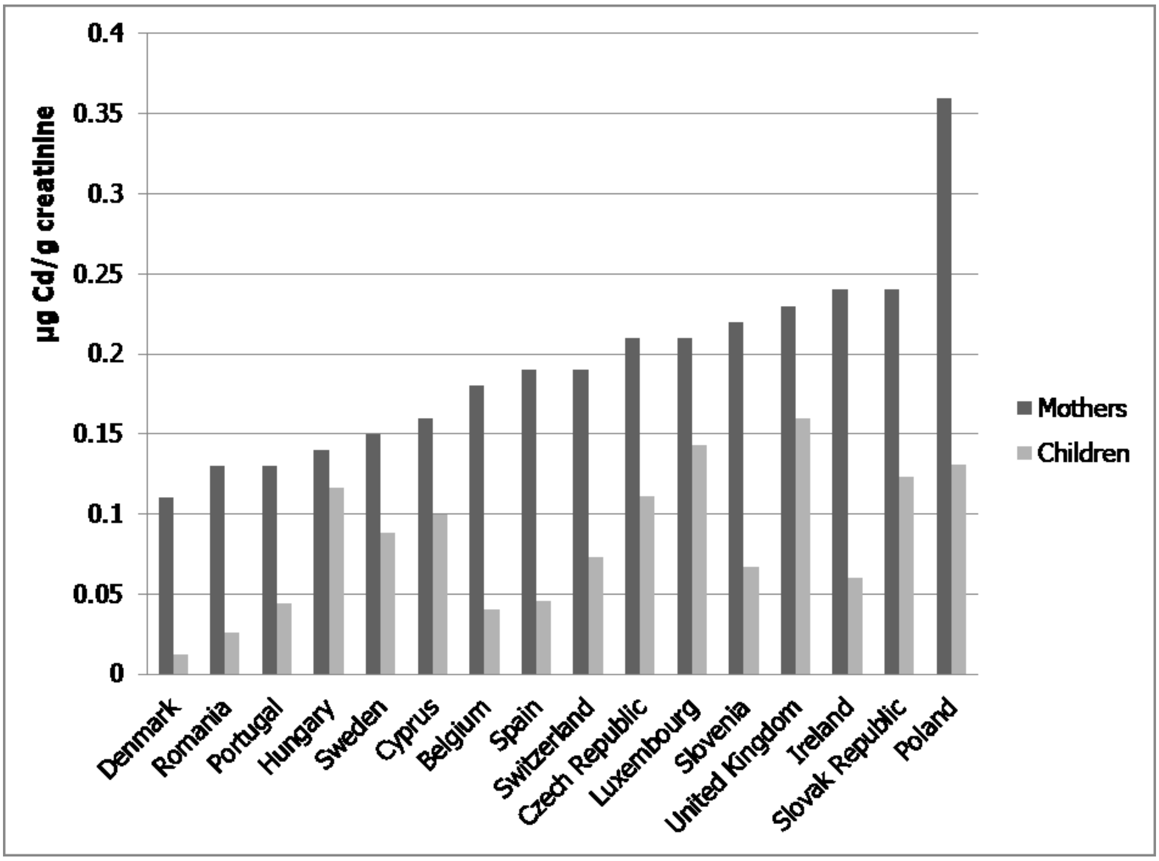

Figure 2.4.4.2-1 Geometric mean urinary cadmium concentrations (µg Cd/g creatinine) in mothers (non-smokers only) and children in Democophes (adapted from Berglund et al., 2014). Countries are sorted by increasing urinary cadmium concentration in mothers.

Based on the same Democophes results, Den Hond et al. (2015) pointed out that cadmium exposure in European mothers is comparable to that in the women in the same age range who participated in US National Health and Nutrition Examination Survey IV. Substantially higher cadmium exposure than that reported in Europe and the US has been found in e.g. non-European cities, China, and other parts of the world, confirming that the exposure to cadmium in Scandinavian countries is at the low end in a global perspective (Hruba et al., 2012; Pawlas et al., 2013; Akesson et al., 2014). However, contrary to lead, which has declined substantially over the last decades, a time trend study in Northern Sweden showed unchanged concentrations of blood cadmium (measured in erythrocytes) from 1990 to 1999 (Wennberg et al., 2006).

2.5 Summary of hazard identification and characterisation

Cadmium is a non-essential metal for animals and plants showing relevant bioaccumulation. Humans are exposed to cadmium by food, water and air, with food as the most important source in non-smokers. Gastrointestinal absorption rates for cadmium ions are 5 to 10% for healthy men and women but bioaccessibility and bioavailability can vary considerably depending on the food composition, e.g. the phytate content, the iron/zinc body status, age, and gender. Generally, the total body burden is higher in women than men. Absorbed cadmium ions are transported in blood in complex with metallothionein and accumulate especially in the kidneys and in liver. Cadmium is also taken up in bone, especially during growth and remodelling. The cadmium body burden increases continuously during life until approximately the age of about 60-70 years, from which it levels off. The overall biological half-life of cadmium in healthy humans is 10 to 30 years.

The most well characterised chronic toxic effects resulting from cadmium exposure are on kidneys and bones. The accumulation of cadmium in cells in the proximal tubules in the kidneys leads to cell dysfunction and cell damage. This leads to decreased tubular reabsorption and therefore increased excretion of low molecular weight proteins as well as increased excretion of markers of cell shedding. Severe cadmium-induced tubular damage is considered to be irreversible and results in the progressive deterioration of renal function, even after cessation of exposure.

Cadmium may induce bone demineralization and increase risk of fractures both by a direct effect on the bone tissue and indirectly via cadmium-induced renal damage.

Cadmium is considered to be carcinogenic. Cadmium does not interact directly with DNA, but is considered genotoxic due to the induction of oxidative stress and inhibition of DNA repair.

The TWI of 2.5 µg/kg bw established by EFSA in 2009 was based on human studies on the dose-response relationship between concentration of cadmium in urine and kidney function. A $BMDL_{05}$ of 4 µg urinary Cd/g creatinine was derived and an adjustment factor of 3.9 was applied, resulting in a reference point of 1.0 µg cadmium/g creatinine in urine. Toxicokinetic modelling indicated that this concentration of cadmium in urine is not reached in 95% of non-smoking women at age 50 if the average weekly dietary cadmium intake does not exceed 2.5 µg cadmium/kg bw.

Comparison of cadmium exposure reported in biomonitoring studies, i.e. measured concentrations of cadmium in urine and blood, shows that levels measured in Norwegian population groups are comparable to levels reported in Sweden and other European countries and at the low end in a global perspective.

3 Exposure assessment

3.1 Occurrence of cadmium in food

The European Food Safety Authority (EFSA) collects cadmium occurrence data. Available data in the EFSA occurrence database now includes more than 178.000 data points for cadmium reported by member states, countries from the European Economic Area and other countries (EFSA, 2012a). The Slovak Republic, then Germany, France, Romania, Spain and Denmark submitted most data. Norway did not submit any occurrence data for cadmium to the database. The food items were mainly analysed from 2003 to 2011. Of the available data, cadmium was not detected or levels were below the limit of quantification (LOQ) in about half of the food samples.

In Europe, the highest concentrations of cadmium were found in algal formulations, cocoa-based products, crustaceans, edible offal, fungi, oilseeds, seaweed and water molluscs (EFSA, 2012a).

VKM has compiled the available Norwegian data for cadmium concentrations in food. The dataset includes food items analysed mainly from 2006 and onwards. Due to limited information on brassica, vegetables analysed from 1993 is included. Norwegian and European occurrence data are compared in Appendix, Table A-1. The data set contained a number of samples with cadmium concentrations below the LOQ, and the VKM therefore chose to use the lower and upper bound approach. The lower bound approach was applied in the following manner: In cases where the analysed cadmium level in food was below the LOQ, the value 0 was used. For the upper bound approach; when the analysed cadmium value was below the LOQ, the LOQ value was used.

The cadmium concentrations for the food categories and items in the two datasets were within a similar range; however, the European dataset included a much larger number of data points than the Norwegian dataset (Table A-1). The Norwegian occurrence data included 11792 data points, whereof 10943 samples were of fish and seafood, while 849 samples covered other food groups. Several food categories are missing or poorly covered in the Norwegian dataset. Following is a comparison of cadmium levels in food groups and food items in Norway and Europe:

The mean upper bound cadmium concentration in bread and rolls on the Norwegian market was 28.4 µg/kg ww ($n = 25$; ranging from <4.50 to 51.0), while in similar European products the mean concentration was 15.7 µg Cd/kg ww ($n = 2078$). For fine bakery wares the mean upper bound cadmium concentrations were 21.3 ($n = 17$) and 16.6 ($n = 1417$) µg/kg ww in Norwegian and European product, respectively.

More details on cadmium concentrations in cereals and cereals in products on the Norwegian market are given in Table A-2. A total of 88 samples have been analysed for cadmium; the mean upper bound concentration was 29.9 µg/kg ww, ranging from 1.30 to 101 µg/kg ww. The highest upper bound cadmium concentrations were found in a breakfast product (107 µg/kg ww, n = 1), wheat bran (74.0 µg/kg ww, n = 4; ranging from 11.0 to 101) and a bread mix (73.0 µg/kg ww, n = 1). The lowest upper bound concentration was found in taco shells/tubs; the cadmium concentration was 4.50 µg/kg ww (n = 2; ranging from <4.00 to <5.00).

In leafy vegetables on the Norwegian market the mean upper bound cadmium concentration was 35.1 µg/kg ww (n = 10; ranging from 19.0 to 135), while in similar European products the mean cadmium concentration was 37.1 µg/kg ww (n = 3414). For potatoes and products the cadmium concentrations were similar; mean upper bound concentrations were 18.6 (n = 21) and 22.4 (n = 2280) µg/kg ww in Norwegian and European product, respectively. The same was seen for water molluscs; the mean upper bound cadmium concentrations were 329 (n = 646) and 319 (n = 3866) µg/kg ww in Norwegian and European molluscs, respectively.

The mean cadmium concentration in chocolate was higher in products on the European market than in products on the Norwegian market; however the Norwegian dataset only includes 5 samples. The mean upper bound cadmium concentrations in chocolate were 21.2 (n = 5) and 81.8 (n = 1286) µg/kg ww in Norwegian and European product, respectively. For milk chocolate the cadmium concentrations were similar; mean upper bound cadmium concentrations were 16.3 (n = 4) and 20.6 (n = 184) µg/kg ww in Norwegian and European product, respectively.

For fish filet and fish based products, the mean cadmium concentrations were higher in products on the European market than in products on the Norwegian market. The mean upper bound cadmium concentrations in fish filet were 5.51 (n = 8219) and 29.5 (n = 11106) µg/kg ww in Norwegian and European product, respectively. For fish based products the mean upper bound cadmium concentrations were 8.29 (n = 88) and 20.7 (n = 869) µg/kg ww in Norwegian and European product, respectively. An overview of cadmium concentrations in different Norwegian caught fish species is given in Table A-3. A total of 8219 samples have been analysed; the mean upper bound cadmium concentration was 5.51 µg/kg ww, ranging from 1.60 to 16.0 µg/kg ww among the different species. The highest mean upper bound cadmium concentrations were found in Norwegian spring spawning herring (10.0 µg/kg ww, n = 800), North Sea herring (9.00 µg/kg ww, n = 862,), mackerel (16.0 µg/kg ww, n = 845) and sprat (12.0 µg/kg ww, n = 32). Lower levels of cadmium were found in Atlantic cod, tusk, saithe, Atlantic halibut, Greenland halibut, redfish and farmed Atlantic salmon (ranging from 1.60 to 3.80 µg/kg ww among the different species).

The cadmium concentration in liver of cod seems to depend on where the fish is caught; the mean upper bound cadmium concentration in liver of cod caught in the Barents Sea and in the Salten area were 205 µg/kg ww (n = 836) and 414 µg/kg ww (n = 23), respectively, while the mean upper bound cadmium concentration in liver of cod caught in the North Sea and along the coast were 76.6 µg/kg ww (n = 434) and 79.0 µg/kg ww (n = 638), respectively (Table A-4). Liver of saithe contained 250 µg/kg ww (n = 1590), and Svolværpostei, a cod roe and liver pâté, contained a mean upper bound cadmium concentration of 30.0 µg/kg ww (n = 2) (Table A-4). Cadmium has not been quantified in fish oil, as expected with a low solubility in oil (Table A-1).

The cadmium concentration in crab brown meat is much higher than in white crab meat. Furthermore, the cadmium concentration in crabs caught along the Norwegian coastline depends on location; the mean cadmium concentrations are much lower in brown and white meat of crabs caught south of Saltenfjorden than in crabs caught north of Saltenfjorden (Saltenfjorden and up to Vesterålen) (Table A-5). In crabs caught south of Saltenfjorden the mean cadmium concentrations were 2120 µg/kg ww (n = 380) in brown meat and 110 µg/kg ww (n = 385) in white meat. Crabs caught north of Saltenfjorden contained 11200 µg Cd/kg ww brown meat (n = 146) and 810 µg Cd/kg ww white meat (n = 149). In the specific Norwegian geographical area Saltenfjorden-Vesterålen the concentration of cadmium in crabs are very high (NIFES, 2012b; Table A-5), and for white crab meat the levels are exceeding the current maximum limit of 0.5 mg/kg wet weight (European Commission, 2014). Trade of crabs caught in this area is prohibited unless it is documented that the cadmium concentration in the white crab meat is below the current maximum limit (Norwegian Food Safety Authority, 2013). Additionally, the Norwegian Food Safety Authority has issued dietary advice for consumption of crabs caught privately due to the high concentration of cadmium (Matportalen, 2011d).

Cadmium concentrations in bivalve molluscs and shrimps are also given in Table A-5. The highest mean cadmium concentrations are found in oysters (Ostrea edulis 520 µg/kg ww, n = 351), scallops (muscle and gonads) (280 µg/kg ww, n =39) and shrimps (peeled) (111 µg/kg ww, n= 2). Lower cadmium levels were found in blue mussels (73.4 µg/kg ww, n = 256) and claw of king crab (20.0 µg/kg ww, n= 23). There is, to VKMs knowledge, no available data for the occurrence of cadmium in crab pâté.

Cadmium concentrations in muscle, liver and kidney of livestock and game are given in Table A-6. Cadmium concentrations were low in meat compared to liver and kidney, and for liver and kidney cadmium concentrations were higher in game and sheep than in cattle, pork and chicken. The highest concentrations of cadmium were found in meat of horse (23.5 µg/kg ww, n = 2, ranging from 15.0 to 32.0), moose (20.0 µg/kg ww, n = 22, ranging from <1.40 to 145), reindeer (11.4 µg/kg ww, n = 7, ranging from 1.50 to 50.8) and deer (9.80 µg/kg ww, n = 12, ranging from <1.40 to 78.8). For liver, the highest concentrations were found in liver of reindeer (600 µg/kg ww, n = 7, ranging from 300 to 1300), moose (550 µg/kg ww, n = 18, ranging from 40.0 to 1850) and sheep (253 µg/kg ww, n = 27, ranging from 33.0 to 690). Concentrations in kidneys were higher than in liver; highest concentrations were found in kidneys of reindeer (4400 µg/kg ww, n = 6, ranging from 4000 to 5000), moose (2800 µg/kg ww, n = 18, ranging from 500 to 12400) and sheep (1281 µg/kg ww, n = 27, ranging from 51.0 to 4993).

An overview of the occurrence of cadmium in Norwegian foods and food groups are given in Figures 3.1-1 and 3.1-2. Please note different scaling in the two figures. Figure 3.1-2 provides similar data as Figure 3.1-1 but excludes crab brown meat and kidneys of terrestrial animals in order to visualise the difference in levels in other foods. The highest upper bound mean concentrations of cadmium were found in brown meat of crabs (irrespectively of where they were caught), kidneys of terrestrial animals, white meat of crab caught north of Saltenfjorden, liver of reindeer and moose, and oysters. High upper bound cadmium concentrations were also found in scallops, liver of sheep, fish liver, white meat of crab caught south of Saltenfjorden, liver of deer and roe deer, and blue mussels. Other food groups with high concentrations of cadmium were herbs, spices and condiments, and legumes, nuts and oilseeds.

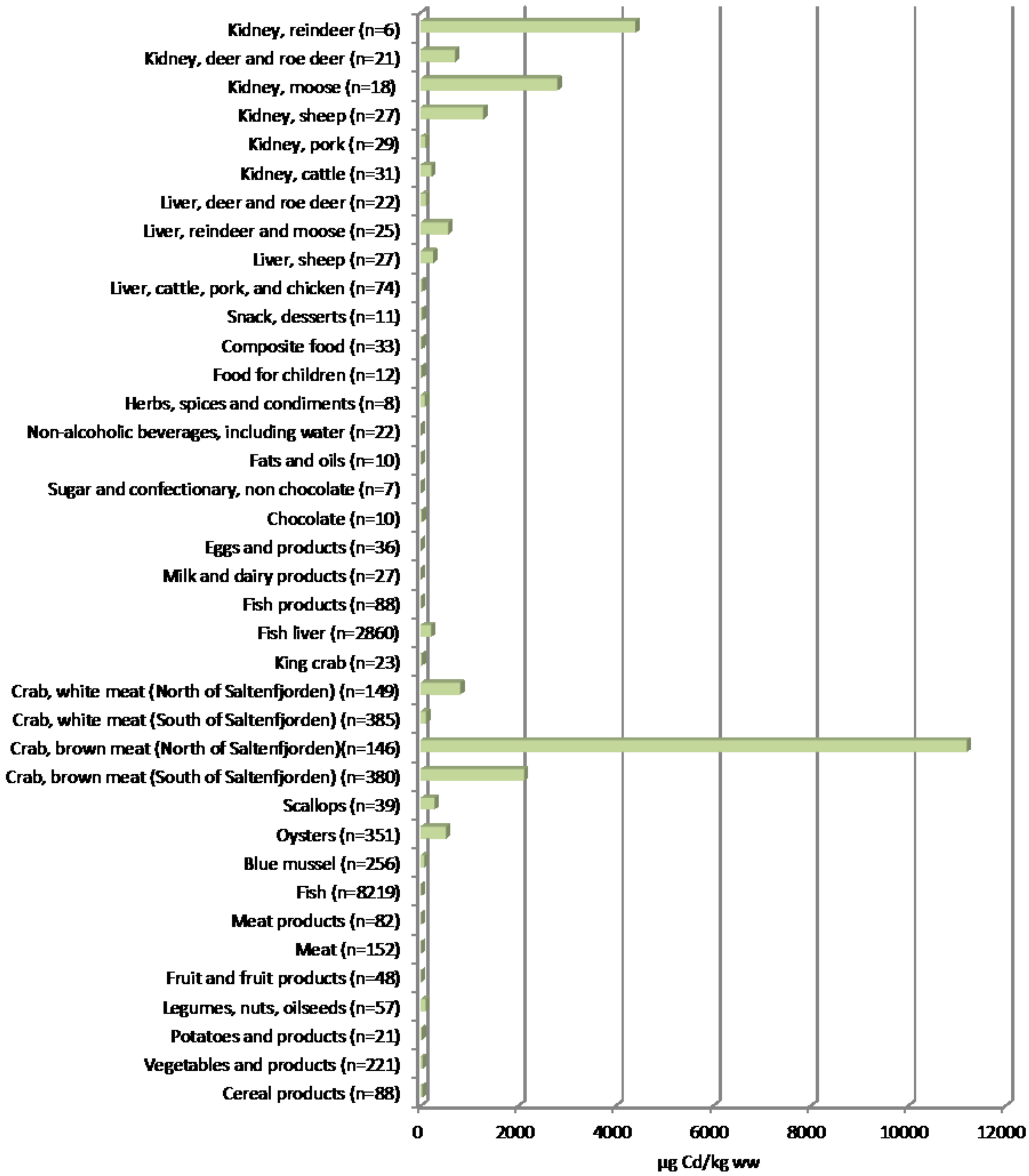

Figure 3.1-1 Mean concentrations of cadmium (Cd) in Norwegian food and food groups, including brown meat of crabs and kidney from terrestrial animals (µg/kg wet weight, upper bound values).

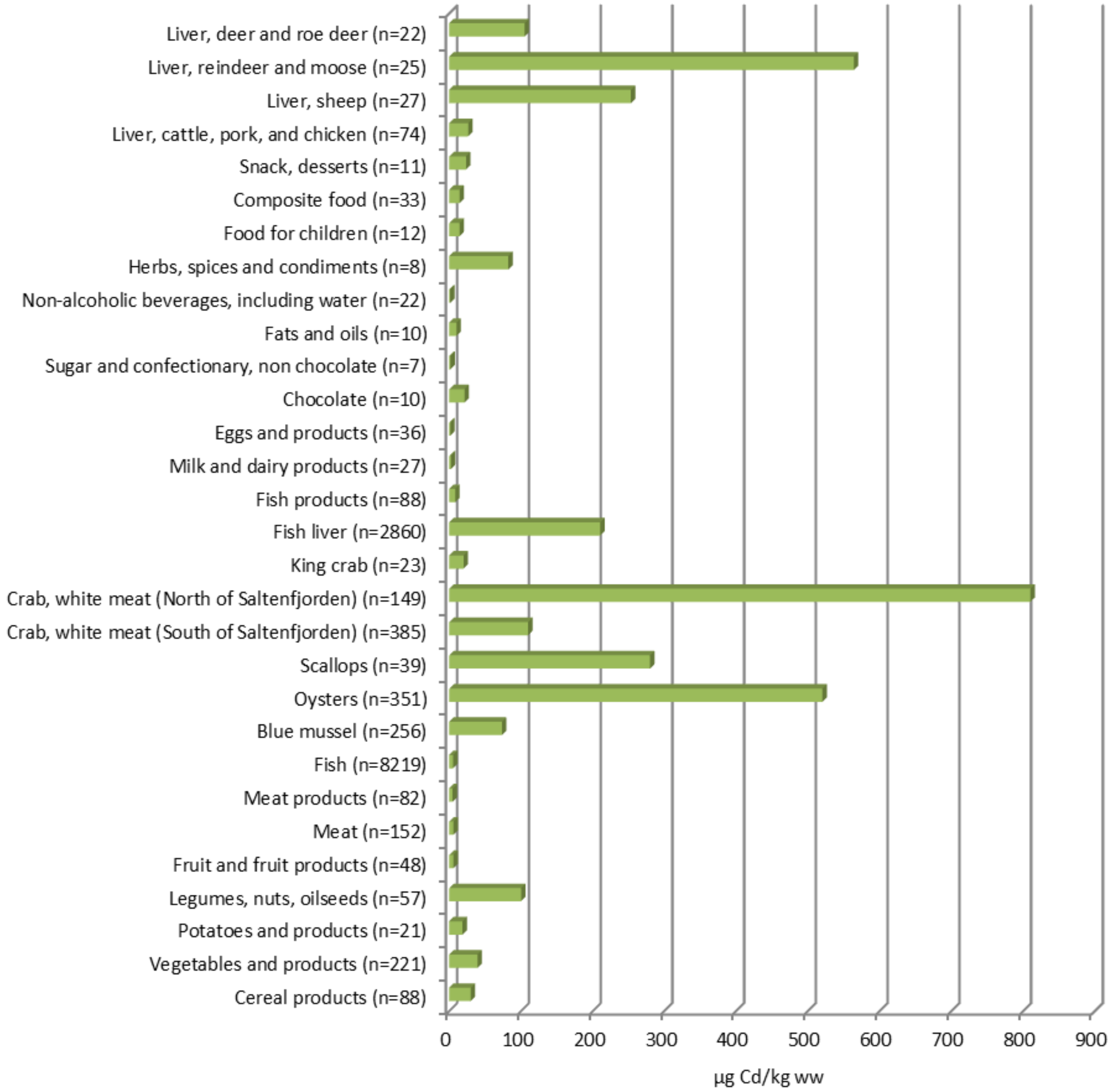

Figure 3.1-2 Mean concentrations of cadmium (Cd) in Norwegian food and food groups, excluding brown meat of crabs and kidneys of terrestrial animals (µg/kg wet weight, upper bound values).

3.2 Previous exposure assessment

3.2.1 Previous exposure assessment in Europe

EFSA conducted exposure assessments to cadmium (Cd) in connection with the risk assessment of cadmium in 2009. The exposure assessment in 2009 was based on food consumption in the EFSA concise database and mean level of cadmium in food in Europe at that time. The exposure assessment indicated that mean dietary intake ranged from 1.9 to 3.0 µg/kg bw/week in different European countries, whereas high exposure (95-percentile) ranged from 2.5 to 3.9 µg/kg bw/week (EFSA, 2009). This indicated that the cadmium exposure from food in Europe was close to the TWI (2.5 µg/kg bw/week).

Later, the EFSA concise food consumption database was replaced by more detailed and refined food consumption information (the "EFSA comprehensive database"). Furthermore, the occurrence data on cadmium in food was supplemented after 2009. Based on this, EFSA published a new cadmium exposure assessment in 2012 (EFSA, 2012a). Average middle bound (MB) estimates (LB and UB in brackets) for the different age classes ranged from a low of 1.56 (1.30-1.82) µg/kg bw per week for the elderly to a high of 4.85 (3.80-5.90) µg/kg bw per week for toddlers. Across age groups, the lowest MB 95-percentile exposure was 2.82 (in elderly) and the highest MB 95-percentile exposure was 8.19 (toddlers) (Table 3.2.1-1).

Table 3.2.1-1 Lower bound (LB), middle bound (MB) and upper bound (UB) means and 95-percentile (P95) dietary cadmium exposure in µg/kg bw per week for each age groups and as a mean and 95-percentile average lifetime exposure calculated by weighting the contribution of each age group according to the number of years covered (different range of countries covered in the respective age group) (EFSA, 2012a)

Age group	N	Mean			P95		
		LB	MB	UB	LB	MB	UB
Infants	876	1.97	2.74	3.50	4.97	6.56	8.42
Toddlers	1597	3.80	4.85	5.90	6.76	8.19	9.84
Other children	8468	3.23	3.96	4.69	5.55	6.58	7.66
Adolescents	6329	1.87	2.20	2.54	3.66	4.17	4.70
Adults	30788	1.41	1.70	1.98	2.72	3.09	3.50
Elderly	4056	1.30	1.56	1.82	2.47	2.82	3.18
Very elderly	1614	1.38	1.63	1.89	2.56	2.87	3.21
Adjusted average[a]	-	1.68	2.04	2.39	3.17	3.66	4.18

[a]The age groups represent 1 year for infants (1.3%), 2 years for toddlers (2.6%), 7 years for other children (9.1%), 8 years for adolescents (10.4%), 47 years for adults (61.0%), 10 years for the elderly (13.0%) and 2 years for the very elderly (2.6%). (Source: EFSA, 2012a)

The results from the different age groups in the survey population were weighted for percent of the number of years the age category made up of an average life span of 77 years. The average middle bound cadmium dietary lifetime exposure was estimated to be 2.04 (1.68-

2.39) µg/kg bw per week. With the assumption that the same individuals retained high exposure throughout life, EFSA also calculated an average 95-percentile middle bound lifetime exposure to be 3.66 (3.17, 4.18) µg/kg body weight per week. This indicated again that the exposure to cadmium in Europe is close to the TWI.

Foods that are consumed in larger quantities, but that contained relatively low levels of cadmium, had the greatest impact on cadmium dietary exposure in Europe (Figure 3.2.1-1). The broad food group contributing most to the exposure were grains and grain products at 26.9%, followed by vegetables and vegetable products at 16.0%, starchy roots and tubers at 13.2%, meat and edible offal at 7.7% and fish and seafood at 7.5% (average across all age groups). Although there was a considerable variation across surveys, grains and grain products, vegetables and vegetable products, and starchy roots and tubers contributed consistently about 50% or more to exposure in all surveys. However, fish and other seafood, meat and edible offal or sugar and confectionary contributed substantially to exposure in some individual surveys (EFSA, 2012a).

There are recent cadmium exposure assessments from Sweden. Since food consumption habits and cadmium exposure in Sweden may be similar to those in Norway because of the close cultural and geographical connections, VKM has summarized intake estimations from Sweden. These studies are relevant because Sweden has explored to what extent national occurrence data would affect dietary cadmium exposure when food consumption data from Riksmaten (a seven days dietary record survey) were used instead of the mean occurrence in Europe (as is used in exposure assessments by EFSA) (Sand and Becker, 2012). The comparison resulted in almost a factor 2 difference in the median exposure. The median Swedish cadmium intake based on mean occurrence level in Europe was 1.7 µg/kg bw/week, whereas the median based on mean occurrence in Sweden was 0.93 µg/kg bw/week. However, the authors stated that differences in occurrence data from different countries does not necessarily mean that the actual contaminant levels in food items are different. It might also be explained by different sampling frame and sampling strategy, or discrepancies in analytical quality. VKM also notes that since the number of Swedish samples was relatively low, differences in mean occurrence may also be random. As in Europe, grain based food and starch rich roots were important cadmium sources in Sweden. In participants with median exposure (45– to 55–percentile), potatoes contributed with 25% of the intake and wheat flour with 24%. In participants with high intake (90– to 99–percentile), potatoes contributed 23%, wheat flour 20%, and seafood with 10%. Particular food items which are rarely eaten but which can contribute substantially to exposure (e.g. shellfish, brown meat of crabs, wild mushrooms) were not covered in the assessment.

Another exposure assessment from Sweden based on the Swedish Mammography Cohort, with repeated dietary intake data covering a period of 20 years, indicated that the median dietary exposure was 0.2 µg/kg bw/day (corresponding to 1.4 µg/kg bw/week) in the period 1987-2007 (Amzal et al., 2009). In this study, bread contributed 36% and potatoes 17% of the exposure.

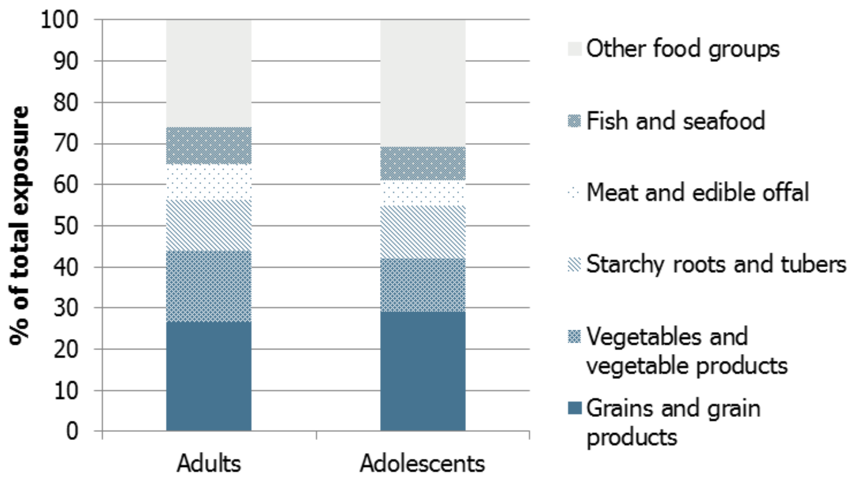

Figure 3.2.1-1 Mean contribution to cadmium intake from main food groups in adults and adolescents (based on EFSA, 2012a). "Other food groups" includes the following food categories: Legumes, nuts and oilseeds; Fruit and fruit products; Milk and dairy products; Eggs and egg products; Sugar and confectionary; Animal and vegetable fats and oils; Fruit and vegetable juices; Non-alcoholic beverages; Alcoholic beverages; Drinking water; Herbs, spices and condiments; Composite food; Snacks, desserts, and Other foods.

3.2.2 Previous exposure assessment in Norway

The Norwegian Fish and Game study is a population based study carried out by the Norwegian Institute of Public Health. The aim of the study was to obtain information about dietary intake and exposure to environmental contaminants. The study was performed in three parts, where part A was conducted in 1999 and surveyed the consumption of certain foods among a representative nation-wide sample of 6015 participants (Meltzer et al., 2002), and part B was a dietary survey in 5502 participants (age 18-79 years) living in 14 coastal (n=2681) and 13 inland (n=2818) municipalities in Norway with ample supplies of fish and/or game but without known point source of persistent organic pollutants and toxic elements (Bergsten, 2004). Participants in part B with high consumption of food items known to contain relatively high concentration of dioxins, polychlorinated biphenyls, mercury or cadmium were invited to participate in part C (n=434). Additionally, a random sample of participants from part B was invited to part C as a reference group (n=267). This selection of participants was done to secure enough participants with a presumed high intake of the contaminants as well as a wide range of dietary exposure.

To the best of our knowledge, the Norwegian Fish and Game study part C is the only Norwegian study that has estimated dietary cadmium exposure in addition to measuring the concentrations of cadmium in urine and blood (Birgisdottir et al., 2013). Participants in Part C (years 2003-2004) donated spot urine and blood samples (described in Chapter 2.4.4.1) and answered a validated food frequency questionnaire assessing the average intake of all food consumed over the last 12 months. The questionnaire contained questions about 233 food items or meals, including detailed questions on seafood and game. Food consumption data was combined with a database of cadmium concentrations in food in order to calculate dietary cadmium exposure. The database was compiled based on cadmium analyses in food and included Norwegian data for meat, fish, shellfish, cereals, vegetables, dried fruit, sweets, fat and drinks. For food items not analysed in Norway the database was supplemented with analytical results from Finland and other nearby countries for milk and milk products, eggs, meat, fruits and berries. The cadmium measurements were performed mainly on raw food between years 1990 and 2005 (Fange, 2005; Birgisdottir et al., 2013).

In the total group (n=179), the median (5– and 95–percentile) estimated dietary cadmium exposure was 15.4 µg/day (8.5, 39.7 µg/d) or 1.5 µg/kg bw/week (0.70, 4.13 µg/kg bw/week). In participants selected due to high intake of food with relatively high content of contaminants, 24% had cadmium intakes above EFSAs TWI of 2.5 µg/kg bw/day (EFSA, 2009), while 8% of participants in the randomly chosen reference group had cadmium intakes above the EFSAs TWI. In a master thesis completed in 2005, a description of cadmium concentrations in food and major contributors to the estimated cadmium intake is available (Fange, 2005). The food groups that contributed most to the estimated cadmium exposure were cereal based food items (particularly wheat), vegetables (particularly potatoes and carrots) and crabs. When food intakes were divided into tertiles (low, median and high intake), cereal products contributed 31, 44 and 54%, respectively of the total cadmium, while vegetables (including potatoes) contributed 19 to 26% respectively. High consumption (upper tertile) of shellfish (primarily crab) contributed 26%, and high consumption of fruit/berries and nuts contributed 9% to the total cadmium intake.

These results show that foods contributing to cadmium exposure among adults in Norway are to a large degree similar to food sources reported in Sweden and in the EU (Amzal et al., 2009; EFSA, 2012a).

3.3 Factors affecting exposure to cadmium in Norway

Previous exposure assessments clearly show that cereal based food and root vegetables, among them in particular potatoes, are the major dietary cadmium sources. VKM has evaluated if there are national factors that would indicate that exposure in Norway is different from the rest of Europe, as reflected in the text below.

Geological factors: A factor that could lead to higher exposure in Norway is that grains and vegetables grown on soil over alum shale which are present in parts of Norway might contain higher cadmium levels. The scarce data on concentration of cadmium in carrots and potatoes from such areas indicate that the concentrations are two to four fold higher than in corresponding products imported or grown elsewhere in Norway (Chapter 1.3). Locally produced vegetables grown in area with alum shale might be an additional cadmium source in particular for individuals consuming their own produce. However, in the general population the vegetables grown in alum shale areas will be diluted by vegetables from other areas, and grains grown in area with alum shale are mixed with grain from other area as well as imported grains. Therefore, in the general population the grains and vegetables grown on alum shale will have little impact on cadmium exposure.

Self-sufficiency: Since a large part (more than 50%) of the grains and vegetables consumed in Norway are imported and 70% of the import comes from the EU (see Chapter 1.3), the EU levels of cadmium in food are highly relevant for Norway.

Occurrence data: The database on cadmium in Norwegian food has improved the latest years, as reflected in Chapter 3.1. Based on the available data, it can however not be concluded that levels in food in Norway are different from those in Europe. Fish is an exception with lower cadmium levels in Norway than in EU, in particular in species most often consumed (cod and salmon). However, since fish is not a major cadmium source, this difference does not largely affect exposure. VKM has discussed the possibility of performing a cadmium exposure assessment for adults based on the national food consumption data Norkost 3 (Totland et al., 2012) combined with Norwegian occurrence data supplemented with EU data for food groups where Norwegian data are missing. However, the EU data that have been published do not provide occurrence data at a detailed level, but rather give the mean occurrence for broader food groups. The use of these data in an exposure assessment based on Norkost 3 would lead to high uncertainty and would not be helpful in risk characterization.

Dietary pattern: A factor that would indicate that the dietary exposure to cadmium could be higher in Norway than in Europe is that the consumption of bran containing cereals is traditionally higher in Norway than in many European countries (EUFIC, 2009; Kyro et al., 2014). Since the bran fraction contains more cadmium, this could lead to higher exposure.

Biomonitoring data in light of estimates of dietary exposure: Studies on levels of cadmium in urine and blood demonstrate that the cadmium exposure among adults in Norway is in a similar range as in Sweden (Chapter 2.4.4.2). There are several dietary intake assessments from Sweden that indicate that the cadmium intake is in the same range as in the rest of Europe (Chapter 3.2.1). EFSA has conducted dietary intake assessments for a large number of European countries based on a large number of European food samples.

Taking all the points above into account, VKM decided not to perform a cadmium exposure assessment in the general Norwegian population. VKM considers that based on available information from cadmium in urine and blood in Norway, the cadmium levels in Norwegian food, and knowledge to Norwegian dietary habits, it can be expected that cadmium exposure among adults in Norway is within the range identified by EFSA, and close to the exposure estimated from Sweden.

However, biomonitoring data as well as dietary exposure assessments show that individuals with preference for particular food items, such as brown meat of crab or liver and/or kidney from different animals may have substantially higher cadmium intake in addition to what is coming from the general diet.

Consumption of particular food items: In Norway, consumption of liver and kidney from terrestrial animals is generally low. In contrast to Norway, consumption of offal and bivalve molluscs is more common in European regions, and is therefore also covered by the European exposure estimates performed by EFSA (EFSA, 2012a). A large part of the Norwegian adult population report consumption of crabs or fish liver at least a few times a year, while a small fraction consume these particular food items more frequently (see Chapter 3.4.1). Since these foods are not eaten on a daily basis, the dietary assessment method used in Norkost 3 (two times 24h dietary recall) does not supply reliable information about consumption (VKM, 2014). In order to estimate cadmium exposure from such sources, VKM has calculated scenarios for the exposure to cadmium from consumption of crabs and fish liver.

3.4 Consumption of particular food items with high cadmium concentrations in Norway

3.4.1 Crab meat

The diet assessment method used in the national survey among adults, Norkost 3, is not suitable to estimate habitual consumption of crab. In Norkost 3 (n=1787) there were 15 persons reported eating crab on one or both consumption days and the intakes were between 17.5 and 150 gram per day (Totland et al., 2012). The participants in Norkost 3 also filled in a Food Propensity Questionnaire with frequency questions. One question addressed frequencies of intake of crab and lobster. It is more usual to eat crab than lobster, but the proportion is unknown. Of the participants, 640 (44%) reported to eat crab/lobster 1-5 times/year, 153 (11%) eat crab/lobster 6-11 times/year, 104 persons (7%) eat crab/lobster once per month, and 34 persons eat crab/lobster 2-3 times per month, and 13 persons reported eating crab/lobster 4 times and more per month.

Information about consumption of crab has also been assessed in some population studies in Norway.

The Norwegian Fish and Game Study was initiated in 1999 to obtain more information about the consumption of specific kinds of fish, shellfish and game in order to obtain information about exposure to environmental contaminants and was conducted in three parts (see Chapter 3.2.2). Crab consumption some time during a year was reported by nearly half (47%) of the 6015 nationally representative participants in Part A (study conducted in 1999). In Part B of the study (conducted in year 2000, n=5502), a large difference in crab consumption was seen between coastal and inland residency, as 65% of the participants living close to the coast had eaten crabs some time during the year or more often, while only about 30% of those living inland had done the same. The answer alternatives for crab consumption were "Never", "A few times during the year", "1-3 times a month" and "Once a week or more". No crab consumption was reported by 35% of participants living in coastal municipalities and by 72% in inland municipalities. The frequency alternative "A few times per year" was reported by 55% and 27%, respectively, "1-3 times per month" by 9% and 1%, respectively, and "Once a week or more" was reported by 1% (n=30) in the coastal municipalities and 0.2% in inland municipalities. It was estimated that high consumers (95-percentile) had an intake of approximately 20 g crab/day (portion size 30 g) and that this corresponded to an annual consumption of about 30 medium-sized crabs (Bergsten, 2004).

Of the 119 women in the MoBa validation study, 99 (83%) did not report any crab consumption, 7 reported once time monthly, 9 reported twice monthly and only one reported weekly consumption of crab as sandwich spread or for dinner. In a larger sample of MoBa participants (n=62099), 86% reported no crab intake, the 95-percentile intake was 0.5 times weekly, and the 99-percentile intake was 1.5 times weekly (personal communication, Anne Lise Brantsæter).

A study conducted in the early 1990s recruited 34 male volunteers (age 40-54 years) living in the Frierfjord area in Norway. All were crab consumers who were recruited non-randomly through announcements in the newspaper and other media. The objective of the study was to assess the role of consumption of crabs from the contaminated fjord area for the exposure to PCBs, PCDDs, and PCDFs. In addition to the 24 crab consumers, 10 control subjects were recruited as reference persons. Of the 24 crab consumers, 15 reported an intake of 10-38 crabs per year while 9 reported >40 crabs per year. The highest reported intake was 150 crabs per year, corresponding to 3 crabs per week (Johansen et al., 1996).

3.4.2 Fish liver

The diet assessment method used in the national survey among adults, Norkost 3, is not suitable to estimate habitual consumption of fish liver. In Norkost 3 (n=1787) only three persons reported eating fish liver and the intakes were between 20 and 39 gram (Totland et al., 2012). The participants in Norkost 3 also filled in a Food Propensity Questionnaire with frequency questions, and 295 persons (20%) reported to eat fish liver 1-5 times/year, 31 (2%) did eat fish liver 6-11 times/year, 22 persons (2%) once per month, seven persons 2-3 times per month, and one person reported eating fish liver 4-5 times per month. Cod roe and liver pâté (in Norwegian: Rognleverpostei) was eaten by 18 participants (1%) in the Norkost 3 interviews. However, when filling in the Food Propensity Questionnaire, 10% reported to eat cod roe and liver pâté at least once a month.

Parts A and B of the Norwegian Fish and Game study asked about consumption of cod liver and saithe liver. In part A, 30% reported any consumption of cod liver and 15% any consumption of saithe liver. As for crab, fish liver was more frequently consumed by people living in coastal than in inland municipalities. Cod liver was reported "1-3 times per month" by 4.9% and 1.4% respectively and "Once a week or more", was reported by 0.6% and 0.4% respectively. Saithe liver was reported "1-3 times per month" by 3.1% and 0.7% respectively and "Once a week or more", was reported by 0.4% in the coastal municipalities and 0.2% in inland municipalities. Most people living by the coast had a consumption of cod and saithe liver of just over zero g per day to approximately 4 g per day. However, there were a few people who reported eating up to about 16 g per day (Bergsten, 2004).

None of the 119 women in the MoBa validation study reported eating fish liver for dinner, while three reported rare intake (1-2 times per month) and one reported 1.5 times weekly. In a larger MoBa sample (n=62009), fish liver for dinner was reported by 1% of the women, while intake of fish liver and roe pâté was reported by 5%. The 95-percentile intake was 0.25 times weekly and the 99th percentile intake was 1.5 times weekly (personal communication, Anne Lise Brantsæter).

3.4.3 Other food items

According to national dietary surveys (Norkost 3), adult consumption of offal (liver and kidney) from domestic animals is very low in Norway, even though liver from most of the domestic animals is commercially available. Kidney and liver from sheep have considerably higher cadmium levels than offal from other domestic animals. Sheep liver is of limited availability, but can be bought in some butcher shops. Kidneys from livestock are mainly used for animal feed (personal communication, Nortura), but is also possible to buy from butcher shops. There are also a few restaurants offering sheep kidneys or liver on the menu and it is possible that such offal is used by local producers in their meat products. It is still reason to believe that consumption of sheep offal in Norway is low and not consumed in large quantities.

Consumption of offal from game was assessed in a Norwegian study of lead shot game consumption (Meltzer et al., 2013). The reported consumption was low (median=0 and mean=0.2 times per month), however, the highest reported intake was 13 times per month. The portion size is unknown.

3.5 Scenarios of cadmium exposure from crab or fish liver consumption

Using an approach of exposure by age group, the mean middle bound dietary cadmium exposures estimated by EFSA (2012a) were 1.7 µg/kg bw per week for adults and 2.2 µg/kg bw per week for adolescents (Chapter 3.2.1). Consequently, considering a TWI of 2.5 µg/kg bw per week for cadmium, only 0.30 µg/kg bw in adolescents and 0.80 µg/kg per week in adults can be allocated to consumption of food that is rarely consumed, but that can contain relatively high cadmium levels, such as crabs or fish liver (Table 3.5-1). Children age groups have cadmium exposure exceeding the TWI, and nothing could be allocated to consumption of rarely eaten food with relatively high cadmium levels (Chapter 3.2.1).

Table 3.5-1 Overview of the calculated age specific mean middle bound weekly dietary intake of cadmium in the European population and the additional amount cadmium allocated to other food sources – per kilo body weight per week

Age group	TWI (µg/kg bw/week)	Chronic mean dietary exposure (EFSA, 2012a) (µg/kg bw/week)	Additional exposure allocated to other food sources (µg/kg bw/week)
Adolescent	2.5	2.2	0.30
Adult	2.5	1.7	0.80

In the national dietary survey Norkost 3, the mean body weight of the adult participants was 77.5 kg and in UNGKOST 2000 (Øverby and Andersen, 2002) the mean body weight for 13-year-olds was 49.5 kg. In the scenarios below, VKM has chosen, as a conservative approach, to use EFSAs default value of 70 kg for adult body weight (EFSA, 2012b) and the national measured body weight for adolescents as no European default value exist for this age group.

Based on the TWI of 2.5 µg/kg bw per week, total exposure to cadmium should not exceed 124 µg per week for adolescent with body weight of 49.5 kg, or 175 µg per week for adults with a body weight of 70 kg (Table 3.5-2). Consequently, 15 µg Cd/week in adolescents (124 minus 109 µg Cd/ week) and 56 µg Cd/week in adults (175 minus 119 µg Cd/ week) can be allocated to consumption of food that is rarely consumed, but that can contain relatively high cadmium levels, such as crabs or fish liver without exceeding TWI (Table 3.5-2). It should be noted that individuals with a body weight below the used mean body weight will have less additional dietary exposure to allocate to other cadmium dietary sources like crabs or fish liver. Likewise, individuals with body weights above the used mean body weights will have more additional dietary exposure to allocate to other cadmium dietary sources.

Table 3.5-2 Cadmium exposure corresponding to intake at the tolerable weekly intake (TWI), the calculated age specific weekly dietary intake of cadmium and the additional amount cadmium allocated to other food sources

Age group	Exposure corresponding to intake at TWI (µg/week)	Chronic mean dietary exposure (EFSA, 2012a) (µg/week)	Additional exposure allocated to other food sources (µg/week)
Adolescent, 49.5 kg[a]	124	109[b]	15
Adult, 70 kg[c]	175	119[d]	56

[a] UNGKOST 2000 (Øverby and Andersen, 2002), [b] age group specific mean middle bound dietary exposure to cadmium for adolescent (2.2 µg Cd/kg bw/week *49.5kg ≈109 µg Cd/week), [c] EFSA default value for adult body weight (EFSA, 2012b), [d] age group specific mean middle bound dietary exposure to cadmium for adults (1.7 µg Cd/kg bw/week *70 kg ≈ 119 µg Cd/ week).

3.5.1 Scenarios of cadmium exposure from crab consumption

The edible parts of crabs (Cancer pagurus) include both brown and white meat. The white meat is found in the claws, legs and shoulder (in Norwegian "støet"), whereas the brown meat is found in the carapace. All brown meat is edible except the crab stomach (in Norwegian "paven") which is removed prior to consumption.

The organ that functions both as liver and pancreas in the crab, the hepatopancreas, is present in the crab brown meat. Cadmium is found in higher concentration in brown than white crab meat due to its accumulation in the liver.

The autumn is the top crab eating season for private catchers. Commercially filled crab shells are available the whole year. The relative amount of white and brown meat of crabs is different in whole crab and commercially available filled crab shells. This is taken into account in the scenarios, as described in Table 3.5.1-1. The composition of brown and white crab meat was based on information in a previous assessment (VKM, 2010) and information from a large producer of filled crab shells (HitraMat as). The amount of edible meat in whole crab used in the previous assessment (160g) is quite similar to amount in filled crab shells (150 g). Consequently 150g is used in these scenarios for both whole crabs and filled crab shells.

Table 3.5.1-1 Composition of brown and white crab meat in filled crab shell and whole crabs

Type of crab meat	Brown meat	White meat
Filled crab shell, commercially available	one third (33%)	two third (67%)
Whole crab, commercially available or privately caught	two third (67%)	one third (33%)

Two variants of tinned crab are available on the Norwegian market. One variant contains white crab meat only, whereas the other (pâté) constitutes of about the same proportions of white and brown crab meat as in filled shells.

The cadmium concentration in crabs caught along the Norwegian coastline is shown in Table 3.5.1-2 and Table A-5. For details see Chapter 3.1.

Table 3.5.1-2 Mean concentration of cadmium in crabs caught along the Norwegian coastline (µg/g)

Location	N	Brown meat µg/g [a]	N	White meat µg/g [a]
South of Saltenfjorden	380	2.1	385	0.11
North of Saltenfjorden up to Vesterålen	146	11	149	0.81

[a] µg per g wet weight (ww). All samples contained cadmium concentrations above the limit of quantification (LOQ) (NIFES, 2012b).

Please note that in Appendix, Table A-5, the cadmium concentration is given in ug/**kg**, whereas in the tables above and below it is given in ug/**g**.

Table 3.5.1-3 Content of cadmium (Cd) in whole crabs and filled crab shells with mean edible amount 150 g

Location	Brown meat			White meat			White + brown meat Cd (µg)
	Cd (µg/g)	Meat in one crab/crab shell (g)	Cd (µg)	Cd (µg/g)	Meat in one crab/crab shell (g)	Cd (µg)	
Whole crabs[a]							
South of Saltenfjorden	2.1	100	212	0.11	50	5.5	218
North of Saltenfjorden	11	100	1120	0.81	50	40	1160
Filled crab shells	2.1	50	106	0.11	100	11	117

[a] For trading it must be documented that the concentration of cadmium in white meat (claw meat) is below the maximum limit of 500 µg/kg wet weight (Norwegian Food Safety Authority, 2013)

3.5.1.1 Scenario of cadmium exposure from crab consumption by adults

In the following scenarios the amount of crab meat that can be consumed in addition to other food without exceeding the TWI is calculated. Taking the mean age specific dietary exposure of 1.7 µg/kg bw/week for cadmium into consideration, the additional dietary exposure allocated to other dietary sources is 56 µg cadmium per week given a body weight of 70 kg (Table 3.5-2).

Whole crabs

Whole crabs caught south of Saltenfjorden are each estimated to contain 218 µg cadmium (Table 3.5.1-3). Therefore, an adult person can eat 0.26 whole crabs per week (56 µg Cd / 218 µg Cd = 0.26) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

The cadmium content of whole crabs caught north of Saltenfjorden up to Vesterålen is 1160 µg (Table 3.5.1-3). A similar calculation as described above results in a consumption of approximately 0.05 crabs/week for adults.

If adults only eat white crab meat from crabs caught south of Saltenfjorden, they can consume white meat from about nine crabs per week (56 µg Cd / 6 µg Cd = 9.3) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

Filled crab shells

A filled crab shell contains 117 µg Cd/shell (Table 3.5.1-3). Therefore, an adult person can eat 0.48 filled crab shells per week (56 µg Cd / 117 µg Cd = 0.48) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

3.5.1.2 Scenario of cadmium exposure from crab consumption by adolescents

In the following scenarios the amount of crab meat that can be consumed in addition to other food without exceeding the TWI is calculated. Taking the mean age specific dietary cadmium exposure of 2.2 µg/kg bw/week for adolescents into consideration, the additional dietary exposure allocated to other dietary sources is 14.9 µg cadmium per week given a body weight of 49.5 kg (Table 3.5-2).

Whole crabs

Considering that a whole crab caught south of Saltenfjorden contains 218 µg cadmium (Table 3.5.1-3) an adolescent can eat about 0.07 crab per week (15 µg Cd / 218 µg Cd = 0.07) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

The cadmium content of whole crabs caught north of Saltenfjorden up to Vesterålen is 1160 µg (Table 3.5.1-3). A similar calculation as described right above results in a consumption of approximately 0.01 crab/week for adolescents.

Considering that adolescents only eat white crab meat from crabs caught south of Saltenfjorden, they can consume white meat (see Table 3.5.1-3) from about 2.5 crabs per week (15 µg Cd / 6 µg Cd = 2.5) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

Filled crab shells

Considering that a filled crab shell contains about 117 µg cadmium (Table 3.4.1-3) an adolescent can eat about 0.13 crab shells per week (15 µg Cd / 117 µg Cd = 0.13) without exceeding the TWI of 2.5 µg/kg bw/week (Table 3.5.1.2-1).

Table 3.5.1.2-1 The amount of crab meat that can be consumed in addition to other food without exceeding the tolerable weekly intake (TWI) of 2.5 µg cadmium per week (Cd/week)

Age group	Additional exposure allocated to other food sources (µg Cd/week)	Number crabs/filled crab shells per week without exceeding the TWI		
		Brown and white meat	White meat only	Filled crab shells
Adult	56 [a]	0.26 crabs [b]	9 crabs	0.48 crab shell
Adolescent	15 [a]	0.07 crabs [b]	2.5 crabs	0.13 crab shell

[a]taken into consideration the age specific background dietary exposure given by EFSA (2012a) and body weight of 70 kg for adult and 49.5 kg for adolescents, [b]for crabs harvested north of Saltenfjorden up to Vesterålen, only 0.05 and 0.01 whole crabs/week can be consumed by adults and adolescents, respectively.

3.5.2 Scenarios of cadmium exposure from fish liver consumption

Eating fish liver is associated with two kinds of traditional fish meals made of cod or saithe. The traditional "mølje" consist of cooked cod, with cooked liver and roe as accompaniments. This dish is mostly eaten in the "mølje" season which is in February-April. Fish liver can also be used as a side dish to cooked saithe, and the high season is in the summer months, June-August. There are regional variations in habitual fish liver consumption, and consumption of fish liver outside the abovementioned seasons cannot be excluded. Fish liver can also be consumed in the form of cod roe and liver pâté (in Norwegian: Rognleverpostei), which may be used as sandwich spread. The proportion of cod liver in cod roe and liver pâté is 25%.

The portion size of fish liver varies between persons. A study by Brustad et al. (2003) addressing vitamin D intake from cod liver consumption reported a variation from a minimum of 33 g to a maximum of 281 g cod liver per meal. The mean cod liver intake was 114 g. However, in the national dietary survey Norkost 1997, in the Norwegian Fish and Game study and in MoBa as well as in a previous VKM risk assessments, a mean portion size of 30 g fish liver has been used (Bergsten, 2004; VKM, 2007).

Table 3.5.2-1 Cadmium levels in cod liver from different harvesting areas, and in saithe liver

Fish liver, species and location	N	Mean* µg/kg ww
Cod liver, North Sea[1]	434	76
Cod liver, North-East Arctic (Barents Sea)[2]	836	205
Saithe liver (Barents Sea)[3]	1590	250

*No values were below the limit of quantification (LOQ), [1]data collected during 2010-2011, (Julshamn et al., 2013a), [2]data collected during 2009-2011 (Julshamn et al., 2013b), [3]data collected during 2010-2013 (NIFES, 2013e; NIFES, 2013f)

Given the TWI of 2.5 µg/kg bw per week and subtracting the chronic mean dietary exposure given by EFSA (2012a), 15 µg Cd/week in adolescents and 56 µg Cd/week in adults can be allocated to consumption of fish liver (Table 3.5-2).

Since there is a general advice not to consume liver from fish caught near the coast, only cod livers from cod harvested in the North Sea and from the North-East Arctic Sea are used in exposure scenarios. The mean concentration in fish liver used in exposure scenarios are shown in Table 3.5.2-1. The amounts of different types of fish liver that can be consumed by adolescents are given is table 3.5.2-2. Adolescents can consume from 60 to 196 g fish liver per week and adults can consume from 224 to 737 g fish liver per week, depending on fish species and location. Depending on portion sizes (30 g or 100 g) this translates into between 2.2 and 25 portions per week in adults and between 0.6 and 6.5 portions per week in adolescents.

Table 3.5.2-2 Amount of cod liver from different harvesting areas and saithe liver that can be consumed in addition to the regular diet without exceeding the tolerable weekly intake of 2.5 µg/kg bw per week for cadmium in adolescents and adults, given as g/week or portions per week with different portion sizes

Fish species	Fish liver, g/week		Fish liver, portions/week			
			Portion size 30g		Portion size 100g	
	Adolescents	Adults	Adolescents	Adults	Adolescents	Adults
Cod liver, North Sea	196	737	6.5	25	2.0	7.4
Cod liver, North-East Arctic	73	273	2.4	9.1	0.7	2.7
Saithe liver	60	224	2.0	7.5	0.6	2.2

Cod roe and liver pâté (Rognleverpostei) is a tinned sandwich spread which contains 25% cod liver and is available on the Norwegian market. Each tin of cod roe and liver pâté (100g) thus contains approximately 25 g cod liver, implying that 9 boxes (adults) or 3 boxes (adolescents) of this sandwich spread can be consumed weekly in addition to regular food without exceedance of the TWI for cadmium.

3.6 Summary of occurrence and exposure assessment

VKM has compiled the available Norwegian occurrence data for cadmium concentrations in food including food items analysed from 2006 and onwards. Comparison of Norwegian and European occurrence data shows that the cadmium concentrations for the food categories and items in the two datasets were within a similar range; however, the European dataset included a much larger number of data points (n ≈ 178000) than the Norwegian dataset (n = 11792 whereof 10943 from fish and seafood). The exceptions are fish filet and fish products (i.e. dishes based on minced fish meat), in which the mean cadmium concentrations were higher in products on the European market than in fish from Norway.

In Norwegian foods and food groups, the highest upper bound mean concentrations of cadmium were found in seafood (brown and white meat of crab, oysters, scallops, fish liver, and blue mussels), liver from game and sheep, herbs, spices and condiments, and legumes, nuts and oilseeds. In Europe, the highest concentrations of cadmium were found in algal formulations, cocoa-based products, crustaceans, edible offal, fungi, oilseeds, seaweed and water molluscs.

EFSA estimated a mean cadmium exposure in Europe between 1.9 and 3.0 µg/kg bw/week in 2009. This indicated that the cadmium exposure from food in Europe was close to the TWI. When updated food consumption and occurrence data became available, EFSA published a new cadmium exposure assessment in 2012 (EFSA, 2012a). Average middle bound estimates (lower bound and upper bound in brackets) for the different age classes ranged from a low of 1.56 (1.30-1.82) µg/kg bw per week for the elderly to a high of 4.85 (3.80-5.90) µg/kg bw per week for toddlers.

Food consumed in large quantities contributed the most to the dietary cadmium exposure in the European population (EFSA, 2012a). These broad food categories were grains and grain products, vegetables and vegetable products, and starchy roots and tubers. Food items contributing the most to the dietary cadmium exposure were potatoes, bread and rolls, fine bakery wares, chocolate products, leafy vegetables and water molluscs.

VKM decided not to perform a cadmium exposure assessment in the general Norwegian population. Based on available information from cadmium in urine and blood in Norway, the cadmium levels in Norwegian food, and knowledge about Norwegian dietary habits, it can be expected that cadmium exposure among adults in Norway is within the range identified by EFSA, and close to the exposure estimated from Sweden. A large part of the Norwegian adult population report consumption of crabs or fish liver at least a few times a year, while a small fraction consume these particular food items more frequently (see Chapter 3.4.1). In order to estimate cadmium exposure from such sources, VKM has calculated scenarios for the exposure to cadmium from crabs and fish liver, and estimated the amount that can be consumed in addition to the general diet without exceeding the TWI of 2.5 µg cadmium per week. The mean exposure calculated by EFSA in 2012 was used as the exposure from food consumed regularly.

In adults the estimated amounts that can be consumed in addition to the general diet without exceeding the TWI correspond to 0.26 crabs per week if whole crab is consumed, 9 crabs per week if only white meat is consumed and 0.48 filled crab shells per week. In adolescents, the respective amounts are 0.07 whole crabs per week, 2.5 crabs per week if only white meat is consumed and 0.13 filled crab shells per week. These scenarios are valid only of crabs caught south of Saltenfjorden.

Depending on fish species and location, the amount of fish liver that can be consumed in addition to the general diet without exceeding the TWI was estimated to be from 224 to 737 g fish liver per week for adults and from 60 to 196 g per week for adolescents.

Cadmium concentrations in liver and kidneys are higher than in meat from the same animal. Compared with liver from sheep and game, cattle, pork and chicken liver have relatively low cadmium concentrations. Consumption of kidney and liver is low in Norway and VKM did not estimate the potential contribution of cadmium from consumption from such food. In contrast to Norway, consumption of offal and bivalve molluscs is more common in European regions, and is therefore also covered by the European exposure estimates performed by EFSA (EFSA, 2012a).

4 Risk characterisation

VKM uses the tolerable weekly intake of 2.5 µg Cd/kg bw/week set by EFSA in 2009 as basis for the present risk characterization. The TWI was based on the increased risk of reduced kidney function in adults after long-term exposure to dietary cadmium. Recent studies indicate that decreased bone mineral density and increased risk of fractions occur at similar exposure levels as reduced kidney function (Chapter 2.4.2). This supports that the EFSA TWI is appropriate.

In the cadmium dietary exposure assessment performed by EFSA (2012a) the average middle bound (MB) estimates (lower bound and upper bound in brackets) for the different age classes ranged from 1.56 (1.30-1.82) µg/kg bw per week for the elderly to 4.85 (3.80-5.90) µg/kg bw per week for toddlers. Across age groups the lowest MB 95-percentile exposure was 2.82 µg/kg bw per week (in elderly) and the highest MB 95-percentile exposure was 8.19 µg/kg bw per week (in toddlers). EFSA concluded that the current average dietary exposure to cadmium for adults in Europe is close to the TWI and the exposure of some subgroups, such as children, vegetarians and people living in highly contaminated areas, could exceed the TWI already at mean intake. The 95-percentile-exposure exceeds the TWI in all age groups. Food is the major source of cadmium exposure in the non-smoking population. The most important food groups in Europe contributing to cadmium exposure were grains and grain products (contributing with 50% or more), followed by vegetables and vegetable products, and starchy roots and tubers. These are foods that are eaten in large quantities, but contain low levels of cadmium. Some food items contain relatively high cadmium concentrations, but are eaten in lower quantities in the general population, but can contribute substantially to cadmium intake at the individual level. Examples of such food items are liver and kidneys, bivalve molluscs, crustaceans, dark chocolate and seeds.

Long-term exceedance of the TWI is of concern as it can increase the risk of developing kidney disease at the population level. VKM agrees with EFSA in that the risk of adverse effects for an individual at the current dietary exposure is low because the TWI is not based on actual kidney damage, but on an early indicator of changes in kidney function, suggesting possible kidney damage later in life. Keeping the exposure for all population groups below the TWI will ensure that the cadmium concentrations in the kidneys will not reach a critical level for reduced kidney function (see Chapters 2.3 and 2.4). Since cadmium accumulates in the kidneys over time (decades), VKM is of the opinion that a short-term exceedance of the TWI (for some weeks or a few months) will not lead to adverse effects in the kidneys as long as the long-term exposure (for several months and years) is below the TWI. VKM therefore considers that the cadmium intake from irregularly consumed food can be averaged over longer time-periods (several months up to a year) than a week.

Specific factors for Norway that might lead to cadmium exposure unlike other European countries

Geological factors: The presence of alum shale in some agricultural areas may increase the level of cadmium in vegetables grown here and thereby increase cadmium exposure in the population (see Chapter 1.3). Vegetables grown in areas with alum shale might be an additional cadmium source in particular for individuals consuming locally grown crop. Little information is available on concentrations of cadmium in food from such areas. Furthermore, grains grown in areas with alum shale are mixed with grains from other area as well as imported grains, and the vegetables grown in alum shale areas will be mixed with vegetables from other areas, thereby reducing the impact on long-term exposure.

Since a large part of the grains and vegetables consumed in Norway are imported (Chapter 1.2), the EU levels for cadmium in food are highly relevant for Norway.

Food consumption patterns: The consumption of bran-containing cereals is traditionally higher in Norway than in many European countries (Chapter 3.3). Since the bran fraction of grain contains more cadmium than the kernel this could lead to higher exposure. However, although the concentration of cadmium in bread and rolls and fine bakery wares appears to be higher in Norwegian samples than in Europeans samples, the number of Norwegian samples is too low and the concentration range too wide to conclude that the levels are different from the average European levels in the same food categories.

Consumption of brown meat of crab and fish liver are particular food habits in Norway that can increase the exposure at the individual level (see below).

Risk characterisation of cadmium exposure from regular food in Norway

VKM has compared cadmium concentrations in food in Norway with those found in European food, and has taken into account the percentage of food imported to Norway, and compared concentrations of cadmium in blood and urine in Norway and Europe. Based on this, VKM concludes that the cadmium exposure among adults in Norway can be expected to be within the range identified by EFSA, and close to the exposure estimated for Sweden. Consequently, VKM has decided not to perform an exposure assessment based on the cadmium concentrations that have been measured in the relatively small number of Norwegian foods, because the uncertainties associated with such an exposure assessment would be too high to conclude if cadmium exposure among adults in Norway was different from that in the rest of Europe.

Based on the information available, VKM concludes that the cadmium exposure of the majority of the Norwegian population is below the TWI, but that some specific population groups probably have exposure above the TWI, which is of concern. VKM is of the opinion that long-term cadmium exposure above the TWI as result from the regular diet is unlikely in Norway, but that exceedance might occur from the additional high consumption of particular food items with high cadmium concentrations.

Risk characterisation of cadmium exposure from particular food items

Bio-monitoring data as well as dietary exposure assessments show that individuals with preference for particular food items, such as crab brown meat or liver and/or kidneys from different animals may have a substantially higher cadmium intake than the general population.

A large part of the Norwegian adult population report consumption of crabs or fish liver at least a few times a year, while a small fraction consume these particular food items more frequently (see Chapter 3.4.1). Consumption of crab brown meat or fish liver is however not common in most European regions and therefore not covered by the exposure estimates performed by EFSA. In scenario exposure assessments VKM calculated how much crab and fish liver could be consumed by adults and adolescents in addition to the regular diet without exceeding the TWI of 2.5 µg/kg bw/week. Since these foods are mainly eaten on a seasonal or non-regular basis, it was stipulated that the associated cadmium exposure would come in addition to the mean exposure from regularly eaten food. The mean dietary exposure calculated by EFSA (2012a) was 1.70 and 2.20 µg cadmium/kg bw/week in adults and adolescents, respectively. For adults, the additional dietary exposure allocated to food items with particular high cadmium concentration has been calculated by VKM to be 0.80 µg/kg bw/week (56 µg cadmium per week given a body weight of 70 kg). For adolescents the corresponding value is 0.30 µg/kg bw/week (14.9 µg cadmium per week given a body weight of 49.5 kg).

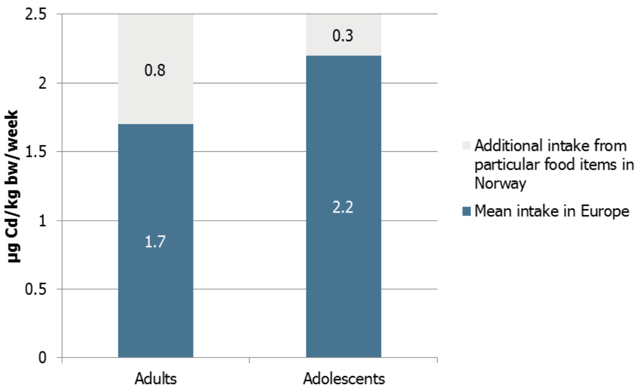

Figure 4-1 Mean middle bound weekly dietary intake of cadmium in adults and adolescents as reported by EFSA (EFSA, 2012a) (dark blue), and amount of cadmium that can be consumed weekly in addition (light blue) without exceeding the TWI of 2.5 µg/kg bw/week.

Scenario exposures were not calculated for children because there are no data on consumption of crab and fish liver for children from national dietary surveys. The exposure assessments from EFSA indicate that children already exceed the TWI for cadmium via their regular diet. Since cadmium accumulates in the kidneys over time, it is not expected that the concentrations in the kidneys in children can reach a level that can cause health damage at the present cadmium levels in regularly eaten food. Furthermore, it was anticipated by VKM based on common knowledge regarding children's food habits that brown crab meat and fish liver are rarely consumed by children. However, if consumed by children, food items with high cadmium concentrations would contribute more to exposure in children than in adolescents and adults because of the low body weight in children and their high energy requirement relative to the body weight.

Crabs: The scenarios of cadmium exposure from crab consumption (Chapter 3.5.1) indicate that adults can eat 0.26 whole crabs per week or 0.48 filled crab shells per week in addition to regular food without exceeding the TWI of 2.5 µg/kg bw/week for cadmium. This corresponds to approximately 1 whole crab per month and 13.5 whole crabs per year or approximately 25 filled crab shells per year for adults. If adults only eat white crab meat, the scenario calculations indicate that they can consume white meat from approximately nine crabs per week (56 µg Cd / 6 µg Cd = 9.3), which corresponds to white meat from approximately 468 crabs per year.

Adolescents can eat as little as 0.07 whole crabs per week in addition to regular food without exceeding the TWI of 2.5 µg cadmium/kg bw/week. This corresponds to approximately 0.3 whole crabs per month, or 3-4 whole crabs per year or approximately 7 filled crab shells per year for adolescents. If adolescents only eat white crab meat, the scenario calculations indicate that they can consume white meat from about 2.5 crabs per week, which corresponds to white meat from approximately 129 crabs per year.

Crab can also be consumed as sandwich spread, as tinned crab pâté is available on the market. According to information obtained from one producer, the composition between brown and white crab meat in this product is quite similar to that in filled crab shells. Therefore, the cadmium exposure from crab pâté is expected to be in a similar range as from filled crab shells, if the amount consumed is similar. Also tinned crab white meat is available, and the cadmium exposure would be similar as described above for white crab meat.

High crab consumption (95-percentile) in the Norwegian Fish and Game study part B corresponded to 30 whole medium size crabs per year (Chapter 3.4.1). In the 24 crab consumers in the Frierfjord study (Grenland), 15 reported intakes of 10-38 crabs per year and 9 reported from 40 and up to 150 crabs per year. In light of the exposure scenarios, the high consumers in both of these studies are likely to exceed the TWI. Hence, VKM concludes that high consumption of crabs in subgroups of the population is of concern if the brown meat is consumed.

When only considering the white meat, the number of crabs (468) that can yearly be consumed by adults without exceedance of the TWI is much larger than the consumption reported in available dietary surveys in Norway (see above). Although no crab consumption data are available for adolescents, consumption of white meat from as much as 129 crabs per year in adolescents is by VKM considered as unlikely. Furthermore, white crab meat consumption is covered in the food surveys used in exposure assessments from EFSA, including those for children. Hence, VKM concludes that cadmium exposure from white crab meat is not of concern in Norway.

Fish liver: The mean concentration of cadmium in fish liver varies with species and location (Chapter 3.5.2). The scenarios on fish liver consumption performed by VKM indicate that adults on average weekly can consume 224 g saithe liver or 273 g cod liver from the North-Eastern Arctic Sea (Barents Sea) or 737 g cod liver from the North Sea weekly in addition to regular food without exceeding the TWI of 2.5 µg cadmium/kg bw/week. Given portion sizes of 30 and 100 gram this corresponds to between 2.2 and 25 liver portions per week (or 9.7 to 106 portions per month) without exceedance of the TWI.

Because of their lower body weight, adolescents can consume less fish liver than adults in addition to regular food without exceeding the TWI for cadmium. The scenarios on fish liver consumption indicate that adolescents on average can consume 60 g saithe liver or 73 g cod liver from the North-East Arctic Sea (Barents Sea) or 196 g cod liver from the North Sea weekly in addition to regular food without exceeding the TWI of 2.5 µg cadmium/kg bw/week. Given portion sizes of 30 and 100 gram this corresponds to between 0.6 and 6.5 liver portions per week (2.6 to 28 portions per month) without exceedance of the TWI.

Information about cod and saithe liver consumption in the Norwegian Fish and Game study Part B showed that most participants had low consumption of cod and saithe liver, estimated to be between 0 and 4 g per day (Chapter 3.4.2). This was based on consumption frequency and a portion size of 30 g. However, consumption up to about 16 g per day (corresponding to 112 g per week) was reported. As indicated above, high consumption (112 g/week) is not of concern regarding cadmium exposure in adults, but may be of concern in adolescents if the liver originates from fish in areas other than the North Sea. If the portion size of fish liver in reality is much higher than 30 g, there is concern in high consumers of fish liver with regard to cadmium exposure.

The available Norwegian data on the consumption of fish liver indicates that such high fish liver consumption over a longer period (months and years) is unlikely, and consequently cadmium exposure from fish liver consumption is not of concern in adults and adolescents. Cod roe and liver pâté is a tinned sandwich spread which contains 25% cod liver and is available on the Norwegian market. Each tin of cod roe and liver pâté (100 g) contains approximately 25 g cod liver, implying that 9 boxes (adults) or 3 boxes (adolescents) of this sandwich spread can be consumed weekly in addition to regular food without exceedance of the TWI for cadmium.

Other food items with high cadmium concentrations

The cadmium concentrations in scallops and oysters are 2-3 fold higher than in white meat from crabs caught south of Saltenfjorden (Chapter 3.1; Figure 3.1-2). There is no information about consumption of these bivalve molluscs in Norway. There were only two shrimps samples available, both with cadmium concentration within the range found in white crab meat. In line with consumption of other crustaceans, high consumption of shrimps may contribute to cadmium exposure.

Offal, in particular offal from game and sheep, contains higher cadmium concentrations than the meat from the same species. Consumption of offal, including offal from game, is generally low (Chapter 3.4.3). However, consumption of game offal has been reported up to 13 times per month in the Norwegian lead and game study, and VKM recognises that high offal consumption will result in high cadmium exposure. In contrast to Norway, consumption of offal and bivalve molluscs is more common in European regions, and is therefore also covered by the European exposure estimates performed by EFSA (EFSA, 2012a).

The scenarios addressing particular food (Chapter 3.5) do not take into account combined consumption of crabs and fish liver. If both crabs and fish liver are consumed less of each item than indicated in the scenarios can be consumed without exceeding the TWI.

5 Uncertainties

The uncertainties associated with the TWI for cadmium described by EFSA (2012a) are also applicable to this assessment. After the TWI was established more information on cadmium and bone mineralisation has become available. It is not known if bone mineralisation is a more appropriate endpoint for cadmium toxicity than reduced kidney function.

VKM is of the opinion that a short-term exceedance of the TWI (for some weeks or a few months) will not lead to adverse effects in the kidneys as long as the long-term exposure (for several months and years) is below the TWI. However, VKM has not addressed whether short-term exceedance of the TWI (for some weeks or months) has the potential to irreversibly decrease bone mineral density. In case cadmium has this potential, averaging cadmium exposure over months and a year may underestimate the risk.

VKM decided not to perform a cadmium exposure assessment in the general Norwegian population (Chapter 3.3) since the use of available occurrence data in an exposure assessment based on Norkost3 would lead to high uncertainty. Instead scenarios of cadmium exposure from consumption of crab brown meat and fish liver which is common in Norway, have been performed. The uncertainties associated with the scenarios are explained below.

Portions size (whole crab and crab shell) and consumption pattern: National dietary surveys are not designed to cover the consumption of rarely eaten foods. In the present opinion there are several of the food items with high concentrations of cadmium that are eaten by a low percentile of the population, or with a low frequency. To get good data on the consumption pattern of these foods like crab and fish liver, specific dietary surveys have to be conducted. The Norwegian Fish and Game study is such a study, but as the data collection was done in the period 1999-2003, the information may be outdated since consumption patterns change over time.

The edible weight of one crab shell and whole crabs is in this opinion 150 grams based on information from the company with the leading market share of filled crab shells. The uncertainties of the edible weight of the commercial filled crab shells are smaller than in the whole crabs. Whole crabs have a variation both in the amount of meat in the shell, and to the proportion of brown and white crab meat. For whole crabs these parameters will vary with the size of the crab and season.

The portion sizes of fish liver vary to a large extent and servings of as little as 5 grams and as much as nearly 300 grams are reported. In this opinion portion sizes of 30 and 100 grams are used as a help for individuals to translate grams of fish into portion sizes.

Body weight: VKM chose, as a conservative approach, to use EFSAs default value of 70 kg for adult body weight while the national survey Norkost 3 (Totland et al., 2012) had a mean body weight of 77.5 kg. For adolescents, VKM used the mean body weight of 49.5 kg for 13-

year-olds from the national survey UNGKOST 2000 study (Øverby and Andersen, 2002; see Chapter 3.5). Individuals with a body weight below the used mean body weight will have less additional dietary exposure to allocate to other cadmium dietary sources like crabs or fish liver. Likewise, individuals with body weights above the used mean body weights will have more additional dietary exposure to allocate to other cadmium dietary sources.

Comparison of Norwegian and European occurrence data of cadmium in food

VKM has compared Norwegian occurrence data with European occurrence data. The cadmium concentrations for the food categories and items in the two datasets were within a similar range; however, the European dataset included a much larger number of data points than the Norwegian dataset. The Norwegian occurrence data included 11792 data points, whereof 10943 samples were of fish and seafood, while 849 samples covered other food groups. The European dataset includes a much larger number of data points (more than 178000 data points), and Norwegian occurrence data are largely outnumbered by EFSA data in all food categories except fish and seafood. Despite the differences in number of data point, there is little uncertainty associated with the comparison of the two data sets.

Analytical measurements

Occurrence data for cadmium concentrations in crab, cod and saithe liver were used in the scenarios. All samples were sampled and prepared following standardised procedures and the uncertainties related to the representativeness of the samples and the samples preparation is low.

The methods used to analyse the cadmium concentrations in crabs, cod and saithe liver (Chapters 3.1 and 3.5) are accredited and quality checked by Norwegian Accreditation. Still, each single method has an uncertainty, a limit of detection (LOD) and a limit of quantification (LOQ). The methods used are harmonized with methods from NMKL (Nordisk metodikk komité), and CEN (European Committee for Standardization).

The contribution of the uncertainty associated with the analytical measurements to the overall uncertainty is low.

Dietary cadmium exposure

Cadmium exposure from regularly consumed food in Europe was set as the mean exposure for Norway. This forms the basis for how much cadmium intake that can be allowed from particular food sources. The background exposure in the population is variable, depending on dietary habits, and the mean value is also affected by particular food consumed in the rest of Europe. Biomonitoring data indicate that cadmium exposure in Norway is in line with Sweden, which is in the lower range in Europe. Although fish liver and crab brown meat not are covered by the European food consumption surveys, white crab meat consumption is not uncommon in Europe and therefore covered in the food surveys. The factors above indicate that using the EFSA (2012a) mean as cadmium exposure from regularly consumed food in the population is conservative, but there will be high variation at the individual level. As a consequence, at the individual level, the amount of cadmium that can be allocated to particular foods is uncertain.

Biomonitoring data

VKM has summarized and compared data from biomonitoring studies that reported cadmium concentrations in urine and/or blood in population studies in Norway and in countries relevant for comparison with Norwegian data. Relatively few biomarker studies in Norway have reported urinary and/or blood cadmium concentration and these are restricted to adult men and women and pregnant women. Hence, there is uncertainty regarding whether these studies can be generalized to all population groups, i.e. children, adolescents, vegetarians.

5.1 Summary of uncertainties

VKM considers the uncertainties in the outcome of the present risk assessment as moderate. The highest uncertainty is associated with the amount of cadmium that can be allocated to particular food items, such as brown meat of crabs, before TWI is exceeded since there is a high individual variation in cadmium exposure from regularly eaten food. The scenarios for exposure to cadmium from consumption of crabs and fish liver are VKM's best estimate for the maximum possible amounts of these particular food items that can be eaten without exceeding the TWI for cadmium.

Table 5.1 Qualitative evaluation of main uncertainties of the cadmium risk characterisation or exposure estimation (+ overestimation, - underestimation)

Source of uncertainty	Direction
Use of kidney toxicity as basis for TWI	+/-
Averaging exposure from occasionally or seasonally consumed food over several months up to a year	-
Use of European mean exposure as background for regularly eaten food	+
Edible weight of whole crab	+/-
Portion size of fish liver	+/-
Use of mean body weight in scenarios	+/-
Generalizability of Norwegian biomonitoring studies	+/-

+: uncertainty likely to cause overestimation of cadmium risk characterisation or exposure estimation.
- : uncertainty likely to cause underestimation of cadmium risk characterisation or exposure estimation.

6 Conclusions

VKM concludes that

- It can be expected that cadmium exposure among adults in Norway is within the range previously identified by EFSA, and close to the exposure estimated for Sweden.
- In dietary exposure estimates from EFSA, toddlers and other children have mean cadmium exposure exceeding the TWI of 2.5 µg/kg bw/week, due to their higher food consumption relative to the body weight. Based on this, VKM expects that the mean dietary cadmium exposure in toddlers and children may exceed the TWI also in Norway.
- Long-term cadmium exposure above the TWI of 2.5 µg/kg bw/week from the regular diet is unlikely in adults in Norway, but exceedance might occur from the additional consumption of food items with high cadmium concentrations, in particular brown meat of crabs.
- Fish liver, bivalve molluscs and offal, in addition to brown crab meat, are particular food items that potentially can lead to added cadmium exposure in Norway.
- Cadmium exposures from these particular food items, which are mainly eaten on a seasonal or non-regular basis, come in addition to the mean exposure from regularly eaten food.
- Short-term exceedance of the TWI (for some weeks or a few months) will not lead to adverse effects in the kidneys as long as the long-term exposure (for several months and years) is below the TWI. Consequently, cadmium exposure from these particular food items can be averaged over longer time-periods than a week (for months and up to one year).
- Scenarios of crab and liver consumption are useful to estimate amounts that can be consumed by adults and adolescents without exceedance of the TWI.
- The mean dietary exposures in adults and adolescents as calculated by EFSA in 2012 can be used as cadmium exposure from regularly eaten food in scenarios on amounts of crabs or fish liver that can be consumed in addition to regularly eaten food without exceedance of the TWI.
- Scenarios for crab and fish liver consumption cannot be calculated for toddlers and children, since they according to EFSA's calculations have mean dietary cadmium exposure exceeding the TWI. Furthermore, consumption data for these age groups are sparse.

- **The results of the scenarios for estimating maximal consumption of crabs (caught south of Saltenfjorden) or fish liver in adults and adolescents without exceedance of the TWI for cadmium indicated that:**
    - Adults can eat approximately 13.5 whole crabs, or approximately 25 filled crab shells, or white meat from approximately 468 crabs per year in addition to regular food.
    - Adolescents can eat approximately 3-4 whole crabs, or approximately 7 filled crab shells, or white meat from approximately 129 crabs per year in addition to regular food.
    - Higher crab consumption than the maximal amount identified in the scenarios for whole crabs or filled crab shells has been reported in Norwegian dietary surveys. High consumers of brown crab meat are at high risk of exceeding the TWI for cadmium.
    - Cadmium exposure from white crab meat is not of concern in Norway.
    - Adults can weekly consume 224 g saithe liver or 273 g cod liver from the North-Eastern Arctic Sea (Barents Sea) or 737 g cod liver from the North Sea in addition to regular food.
    - Adolescents can weekly consume 60 g saithe liver or 73 g cod liver from the North-East Arctic Sea (Barents Sea) or 196 g cod liver from the North Sea weekly in addition to regular food.
    - The available Norwegian data on consumption of fish liver indicate that such high fish liver consumption over a longer period (months and years) is unlikely, and consequently VKM concludes that cadmium exposure from fish liver consumption is not of concern in adults and adolescents.

7 Answers to the terms of reference

Evaluate whether the Norwegian population or subgroups of the population have different food consumption patterns, which could lead to different dietary cadmium exposure than reported in other European population groups.

Previous exposure assessments in Europe and Scandinavia, including Norway, clearly show that cereal based food and root vegetables, particular potatoes, are the major dietary cadmium sources in the general population. These are, however, not the food groups with the highest cadmium concentrations. The highest concentrations are found in offal, bivalve molluscs and crustaceans (e.g. crabs), and previous exposure assessments have shown that high consumption of such food can be associated with high cadmium exposure at the individual level. There is large variation at the individual level regarding consumption of particular food items (e.g. crab brown meat) that can be important contributors to cadmium exposure in addition to the exposure from the regular diet.

VKM has evaluated if there are national factors (geological factors, self-sufficiency rate, national occurrence data and food consumption habits) that would indicate that exposure in Norway is different from the rest of Europe. VKM has also evaluated available national and European data on concentrations of cadmium in blood and urine in relation to estimated dietary intakes. VKM concludes that it can be expected that cadmium exposure among adults in Norway is within the range previously identified by EFSA, and close to the exposure estimated for Sweden. VKM is of the opinion that long-term cadmium exposure above the TWI of 2.5 μg/kg bw/week as result from the regular diet in adults is unlikely in Norway, but that exceedance might occur from the additional high consumption of food items with high cadmium concentrations, in particular brown meat of crabs. In dietary intake estimates from EFSA, toddlers and other children have mean cadmium intake exceeding the TWI, due to their higher food consumption relative to the body weight. Based on this, VKM expects that the mean dietary cadmium intake in toddlers and children may exceed the TWI also in Norway.

Assess the potential health risk regarding consumption of brown meat of crabs.

Crab brown meat contains much higher concentration of cadmium than any other food item commonly consumed in Norway. In contrast to food habits in large parts of Europe, crab brown meat is traditionally eaten in Norway. Considering the mean concentration of cadmium in crabs from south of Saltenfjorden, consumption of one whole crab (approximately 150 g of total crab meat, 218 μg cadmium) results in the intake of 3.1 μg cadmium/kg bw, which is an exceedance of the TWI from crab meat alone and comes in addition to the exposure from the regularly eaten diet. VKM concludes that consumers of brown meat of crab are at high risk of exceeding the TWI for cadmium of 2.5 μg/kg bw/week.

Long-term exceedance of the TWI is of concern as it can increase the risk of developing kidney disease in the population. Keeping the exposure for all population groups below the TWI will ensure that the cadmium concentrations in the kidneys will not reach a critical level for reduced kidney function. Since cadmium accumulates in the kidneys over time (decades), VKM is of the opinion that a short-term exceedance of the TWI (for some weeks or a few months) will not lead to adverse effects in the kidneys as long as the long-term exposure (for several months and years) is below the TWI. VKM therefore considers that the cadmium intake from crabs can be averaged over longer time-periods (for months and up to one year) than a week.

Identify how much crab can be eaten at different levels of contamination – both by children and adults - without exceeding the TWI.

Since crabs are mainly eaten on a seasonal or non-regular basis, it was stipulated that the associated cadmium exposure would come in addition to the mean exposure from regularly eaten food. In scenario exposure assessments, VKM calculated how much crab could be consumed by adults and adolescents in addition to the regular diet without exceeding the TWI of 2.5 µg/kg bw/week. The mean dietary cadmium exposure calculated by EFSA in 2012 was 1.70 and 2.20 µg/kg bw/week in adults and adolescents, respectively. For adults, the additional dietary exposure allocated to food items with particular high cadmium concentration has been calculated by VKM to be 0.80 µg/kg bw/week (56 µg cadmium per week given a body weight of 70 kg). For adolescents the corresponding value is 0.30 µg/kg bw/week (14.9 µg cadmium per week given a body weight of 49.5 kg).

Exposure scenarios were not calculated for children because there are no data on consumption of crab in children from national dietary surveys. It was, however, anticipated by VKM based on common knowledge regarding children's food habits that crab brown meat are rarely consumed by children. However, if consumed by children, crabs would contribute more to the exposure in children than in adolescents and adults because of the low body weight in children and their high energy requirement relative to the body weight.

Brown meat of crab contains higher concentrations of cadmium than white meat. Whole crabs contain a higher percentage of crab brown meat than commercially available filled crab shells, and this was taken into account in the scenarios.

The available data on occurrence of cadmium in crabs from 47 sites along the Norwegian coastline do not indicate systematic regional differences, with the exception of crabs from north of Saltenfjorden where the cadmium concentrations were substantially higher than in the rest of the samples. In order to identify how much crab meat that can be consumed, the mean cadmium level in brown and white meat from crabs from the rest of Norway south of Saltenfjorden and in crabs from north of Saltenfjorden have been used in scenario exposure estimates. The Norwegian Food Safety Authority has issued a specific warning against consumption of all parts of crabs caught north of Saltenfjorden up to Vesterålen. Scenario calculations showed that very few crabs originating from north of Saltenfjorden can be consumed yearly (approximately 2.5 crabs in adults) without exceeding the TWI. The mean number of crabs originating from south of Saltenfjorden that can be consumed without exceeding the TDI is presented below.

Scenarios of cadmium exposure from crab consumption indicate that adults can eat 0.26 whole crabs per week or 0.48 filled crab shells per week in addition to regular food without exceeding the TWI of 2.5 µg/kg bw/week for cadmium. This corresponds to approximately 1 whole crab or two filled crab shells per month. Averaged over a year, it corresponds to 13.5 whole crabs or approximately 25 filled crab shells per year for adults. If adults only eat white crab meat, they can consume white meat from approximately nine crabs per week.

Adolescents can eat as little as 0.07 whole crabs per week in addition to regular food without exceeding the TWI of 2.5 µg/kg bw/week for cadmium. This corresponds to approximately 0.3 whole crabs or 0.6 filled crab shells per month. Averaged over a year, this corresponds to 3-4 whole crabs per year or approximately 7 filled crab shells per year for adolescents. If adolescents only eat white crab meat, they can consume white meat from about 2.5 crabs per week, which corresponds to white meat from approximately 129 crabs per year.

Crab can also be consumed as sandwich spread as tinned crab pâté is available on the market. According to information obtained from one producer, the composition between brown and white crab meat in this product is similar to that in filled crab shells. Therefore, the cadmium exposure from crab pâté is expected to be in a similar range as from filled crab shells, if the amount consumed is similar. Additionally, tinned crab white meat is available, and the cadmium exposure from this product would be similar to that described above for white crab meat, if similar amounts are consumed.

The estimated amounts of crabs that can be consumed without exceedance of the TWI do not take into account cadmium exposure from other food categories that could give added exposure (see below). If such food items are consumed fewer crabs can be consumed.

Identify specific foods or categories of food other than crab which would lead to an added cadmium exposure – both for the general population in Norway and specific groups

Based on the mean concentrations of cadmium, VKM identified fish liver, bivalve molluscs and offal in addition to brown crab meat as particular food items that potentially can lead to added cadmium exposure in Norway.

Fish liver: Fish liver is traditionally eaten in Norway. This is not consumed in most European populations. Cadmium exposure from fish liver has been addressed by scenario exposures by VKM. The same underlying cadmium exposure from regularly eaten food as in the scenarios for crabs was used (see above).

The mean concentration of cadmium in fish liver varies with species and location. The scenarios for fish liver consumption performed by VKM indicated that adults can in average consume 224 g saithe liver or 273 g cod liver from the North-Eastern Arctic Sea (Barents

Sea) or 737 g cod liver from the North Sea per week in addition to regular food without exceeding the TWI of 2.5 µg cadmium/kg bw/week. There is little information about the portion sizes of fish liver. Given portion sizes of 30 and 100 gram this corresponds to between 2.2 and 25 liver portions per week (or 9.7 to 106 portions per month) that can be eaten without exceedance of the TWI.

Because of their lower body weight, adolescents can consume less fish liver than adults in addition to regular food without exceeding the TWI for cadmium. The scenarios for fish liver consumption indicated that adolescents can in average consume 60 g saithe liver or 73 g cod liver from the North-East Arctic Sea (Barents Sea) or 196 g cod liver from the North Sea per week in addition to regular food without exceeding the TWI of 2.5 µg cadmium/kg bw/week. Given portion sizes of 30 and 100 gram this corresponds to between 0.6 and 6.5 liver portions per week (2.6 to 28 portions per month) that can be eaten without exceedance of the TWI.

The available Norwegian data on the consumption of fish liver indicates that weekly consumption of fish liver over a longer period (months and years) is unlikely, and consequently cadmium exposure from fish liver consumption is not of concern in adults and adolescents.

Cod roe and liver pâté (Rognleverpostei) is a tinned bread spread which contains 25% cod liver and is available on the Norwegian market. Each tin of cod roe and liver pâté (100g) thus contains approximately 25 g cod liver, implying that 9 boxes (adults) or 3 boxes (adolescents) of this sandwich spread can be consumed weekly in addition to regular food without exceedance of the TWI for cadmium.

Scenario exposures were not calculated for children because there are no data on consumption of fish liver in children from national dietary surveys. It was however assumed by VKM based on common knowledge regarding children's food habits that fish liver is rarely consumed by children. However, if consumed by children, fish liver would contribute more to exposure in children than in adolescents and adults because of the low body weight in children and their high energy requirement relative to the body weight, and they already have a mean cadmium exposure above the TWI from the regular diet as estimated by EFSA.

The estimated amounts of fish liver that can be consumed without exceedance of the TWI do not take into account cadmium exposure from other food categories that could give an added exposure, e.g. crab meat. If such food items are consumed, less fish liver can be consumed.

Scallops, oysters, shrimps and offal: The cadmium concentrations in scallops and oysters are 2 to 3-fold higher than in white meat from crabs caught south of Saltenfjorden. Information about cadmium concentration in shrimps was only available from two samples, both with cadmium concentrations within the range found in white crab meat. In line with the consumption of white meat from other crustaceans, high consumption of shrimps may contribute to high cadmium exposure. Offal, in particular offal from game and sheep, contains higher cadmium concentrations than the meat from the same species. VKM recognises that high offal consumption will result in high cadmium exposure. However, consumption of offal, including offal from game, and bivalve molluscs is generally low in Norway, although high consumption in some population groups cannot be excluded. In contrast to Norway, consumption of offal and bivalve molluscs is more common in European regions, and is therefore also covered by the European exposure estimates performed by EFSA.

8 Data gaps

There is a need for updated information on consumption of food that are rarely consumed, but that may contain high concentrations of contaminants and therefore may contribute to high exposure at the individual level. This should cover children, adolescents and adults as well as vegetarians.

There is a lack of information about cadmium levels in organically produced vegetables, particularly if grown in alum shale areas.

There is a need for more data on occurrence both in commonly consumed food items as well as in food items considered as risk food for cadmium. There are relatively few biomarker studies in Norway that reported urinary and/or blood cadmium concentration. There is a need for systematic human biomonitoring studies and Norwegian participation in European collaborative biomarker studies. Such participation is essential to confirm whether cadmium exposure is within tolerable levels in Norway.

A Total Diet Study would be helpful to reduce the uncertainty in the estimates of the mean dietary cadmium exposure in Norway.

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Appendix

Occurrence of cadmium in food – European and Norwegian data

Table A-1 European cadmium (Cd) levels as reported by EFSA (2012a) compared with cadmium levels in Norway as reported in different national analysis reports, given as lower bound (LB) and upper bound (UB) mean µg/kg wet weight (ww), and minimum (Min) and maximum (Max) Cd level

European data (EFSA 2012)		µg/kg ww		Norwegian data	µg/kg ww			
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Grains and products*	280	35.1	41.0	7[a]	16.0	16.0	1.30	30.0
Grains for humans	9297	32.5	34.3	2[a]	5.80	5.80	2.50	9.00
Grain milling products	3388	23.9	25.7	11[a,b]	50.8	50.8	10.0	101
Bread and rolls	2078	14.6	15.7	25[a,c]	28.0	28.4	<LOQ	51.0
Pasta (raw)	614	21.2	22.1	5[a]	35.0	35.0	13.0	65.0
Breakfast cereals	678	19.6	21.2	21[a,b]	33.4	33.4	2.10	107
Fine bakery wares	1417	15.1	16.6	17[a]	21.3	21.3	5.40	39.0
Vegetables and products*	840	16.7	17.9	-	-	-	-	-
Root vegetables	2091	24.4	68.3	24[#,a,b,d]	52.2	52.2	3.60	170
Bulb vegetables	777	12.1	13.2	5[d]	44.0	44.0	18.0	81.0
Fruiting vegetables	2694	6.02	8.53	2[a]	0.00	1.50	<LOQ	< LOQ
Brassica vegetables	1952	5.39	7.47	61[a,b,d,e]	6.40	6.40	1.00	10.0
Leaf vegetables	3414	35.6	37.1	10[a,b,d]	35.1	35.1	19.0	135
Legume vegetables	233	2.89	5.89	4[b]	6.10	6.10	1.80	12.0
Stem vegetables (fresh)	732	23.9	25.9	-	-	-	-	-
Chicory roots	65	25.4	25.5	-	-	-	-	-
Seaweeds	202	1122	1122	-	-	-	-	-
Tea and infusions (solid)	6044	55.1	55.5	10[a]	50.5	50.5	15.0	130
Cocoa powder	732	183	183	-	-	-	-	-
Coffee beans	4065	11.0	13.0	-	-	-	-	-
Coffee imitates (solid)	210	13.0	13.6	-	-	-	-	-
Vegetable products	349	10.8	11.5	85[a,b]	11.3	11.3	0.40	86.0

European data (EFSA 2012)				Norwegian data				
		µg/kg ww			µg/kg ww			
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Fungi, cultivated	1926	134	136	20[a,b]	250	250	3.40	1018
Fungi, wild, edible	791	344	345	-	-	-	-	-
Starchy roots and tubers*	-	-	-	-	-	-	-	-
Potatoes and products	2280	21.0	22.4	21[#,a,b,d]	18.6	18.6	6.50	65.0
Other roots and tubers	852	14.0	14.2	-	-	-	-	-
Legumes, nuts, oilseeds*	14	27.7	33.5	3[b]	108	108	44.0	235
Legumes no pods	118	3.21	5.77	-	-	-	-	-
Legumes dried	2267	19.6	21.3	19[a,b]	23.4	23.4	4.70	56.0
Tree nuts	1368	34.2	38.1	20[b]	84.5	84.5	1.00	280
Oilseeds	3496	371	371	15[a,b]	217	217	12.0	580
Fruit and fruit products*	116	7.09	8.90	-	-	-	-	-
Citrus fruits	647	1.16	4.06	-	-	-	-	-
Pome fruits	1505	3.61	6.46	2[a]	0.00	1.50	<LOQ	< LOQ
Stone fruits	470	1.06	6.01	-	-	-	-	-
Berries and small fruits	1055	2.59	5.19	12[b]	18.7	18.7	2.70	40.0
Olives for oil production	5	0.00	1.00	-	-	-	-	-
Miscellaneous fruits	528	2.92	5.46	1[a]	0.00	1.50	<LOQ	< LOQ
Dried fruits	403	2.25	7.18	-	-	-	-	-
Jam and spreads	192	2.87	8.85	-	-	-	-	-
Other fruit products	602	3.17	5.74	33[a,b]	1.50	1.50	0.30	6.20
Meat and edible offal*	908	8.30	15.5	1[a]	4.20	4.20	4.20	4.20
Livestock meat	15462	7.60	15.0	88[a,f]	1.60	2.20	<LOQ	32.0
Horse meat**	1402	359	366	2[f]	23.5	23.5	15.0	32.0
Poultry	4821	3.21	12.8	14[f]	0.00	1.40	<LOQ	<LOQ
Game mammals	2479	3.04	5.69	51[f]	12.5	13.1	<LOQ	145
Game birds	680	1.78	7.63	-	-	-	-	-
Mixed meat	184	1.23	4.25	-	-	-	-	-
Edible offal	18296	315	319	74[£,a,f]	26.4	26.4	2.90	145
Preserved meat	416	2.61	12.1	3[a]	0.00	1.50	<LOQ	<LOQ
Sausages	2663	6.19	25.6	2[a]	0.95	1.70	<LOQ	1.90
Meat specialities	88	2.64	6.72	-	-	-	-	-
Pâtés and terrines	310	4.86	17.7	2[a]	12.9	12.9	9.80	16.0

European data (EFSA 2012)				Norwegian data				
		µg/kg ww				µg/kg ww		
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Meat imitates	311	22.2	23.6	-	-	-	-	-
Fish and seafood*	1294	175	177	4060[a,g,n]	764	764	<LOQ	45000
Fish filet	11106	22.6	29.5	8219[h,m]	4.90[§]	5.51	<LOQ	1500
Fish products	869	17.3	20.7	88[€,a,i]	8.29	8.29	2.00	40.0
Fish roe	112	49.0	51.9	2[a]	1.30	2.00	<LOQ	2.60
Crustaceans	2194	128	136	559[¥,a, n]	293	293	1.00	3700
Water molluscs	3866	316	319	646[j, o]	329	329	40.0	2300
Frogs' legs	97	204	209	-	-	-	-	-
Milk and dairy products*	60	4.98	7.53	1[a]	1.70	1.70	1.70	1.70
Liquid milk	3196	0.49	1.61	16[a,f]	0.43	1.56	<LOQ	3.90
Goat milk**	55	16.3	18.1	-	-	-	-	-
Milk based beverages	17	8.06	9.47	-	-	-	-	-
Concentrated milk	455	4.29	11.0	-	-	-	-	-
Whey beverages	10	3.93	5.30	-	-	-	-	-
Cream and products	651	0.72	17.1	-	-	-	-	-
Fermented products	893	1.26	8.41	-	-	-	-	-
Lactose	4	0.00	11.5	-	-	-	-	-
Cheese	2872	3.24	18.3	7[a]	0.00	1.50	<LOQ	<LOQ
Milk and imitates	60	8.93	7.06	3[a]	3.87	4.40	<LOQ	8.10
Eggs and products*	25	1.68	7.06	-	-	-	-	-
Eggs, fresh	1183	1.27	5.39	36[f]	0.00	1.40	<LOQ	< LOQ
Eggs, powder	10	0.00	20.8	-	-	-	-	-
Sugar and confectionary*	156	11.7	19.6	1[a]	6.50	6.50	6.50	6.50
Sugars	361	1.97	4.30	-	-	-	-	-
Sugar substitutes	2	18.0	18.0	-	-	-	-	-
Chocolate	1286	80.1	81.8	5[a]	21.2	21.2	15.0	41.0
Bitter chocolate**	30	123	123	-	-	-	-	-
Bitter-sweet chocolate**	58	135	135	1[a]	41.0	41.0	41.0	41.0
Milk chocolate**	184	18.7	20.6	4[a]	16.3	16.3	15.0	17.0
Confectionery (non-chocolate)	395	5.60	8.70	6[a]	0.00	1.50	<LOQ	<LOQ
Dessert sauces	14	14.8	14.9	-	-	-	-	-

European data (EFSA 2012)				Norwegian data				
		µg/kg ww		µg/kg ww				
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Molasses and other syrups	178	2.64	3.91	-	-	-	-	-
Honey	2269	3.61	14.4	1[f]	0.00	1.40	<LOQ	<LOQ
Fats and oils*	10	0.00	4.53	-	-	-	-	-
Animal fat	1090	2.41	5.40	-	-	-	-	-
Fish oil	30	17.3	23.9	10[k]	0.00	10.0	<LOQ	<LOQ
Vegetable fat	163	5.96	7.10	-	-	-	-	-
Vegetable oil	636	4.14	5.78	-	-	-	-	-
Fats of mixed origin	2	25.0	35.0	-	-	-	-	-
Margarine and similar	55	1.82	7.33	-	-	-	-	-
Fruit and vegetable juices*	118	2.49	3.39	-	-	-	-	-
Fruit juice	1944	2.16	4.85	-	-	-	-	-
Concentrated fruit juice	9	0.44	1.64	-	-	-	-	-
Fruit nectar	169	0.48	3.79	-	-	-	-	-
Mixed fruit juice	62	1.31	4.98	-	-	-	-	-
Powdered fruit juice	25	2.24	2.84	-	-	-	-	-
Vegetable juice	218	8.90	10.3	-	-	-	-	-
Mixed vegetable juice	8	4.75	11.0	-	-	-	-	-
Mixed fruit/ vegetable juice	14	3.59	7.38	-	-	-	-	-
Non-alcoholic beverages*	44	44.1	44.9	2[a]	7.20	7.20	3.30	11.1
Soft drinks	972	0.98	2.07	4[a]	2.15	2.15	1.70	2.60
Tea (Infusion)	1511	0.92	0.93	5[a]	0.27	0.27	0.04	0.70
Coffee (Beverage)	813	0.61	0.72	6[a]	0.24	0.24	<LOQ	0.50
Coffee imitates beverage	35	0.72	0.75	-	-	-	-	-
Cocoa beverage	2196	2.75	2.85	2[a]	0.89	0.89	0.27	1.50
Alcoholic beverages*	105	0.78	1.51	-	-	-	-	-
Beer and similar	1150	0.69	2.85	-	-	-	-	-
Wine	2604	0.55	1.93	-	-	-	-	-
Fortified and liqueur wines	34	0.35	0.71	-	-	-	-	-
Wine-like drinks	113	0.84	1.48	-	-	-	-	-
Liqueur	26	5.40	6.68	-	-	-	-	-
Spirits	30	1.22	1.74	-	-	-	-	-

European data (EFSA 2012)				Norwegian data				
		µg/kg ww		µg/kg ww				
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Alcoholic mixed drinks	120	1.22	1.74	-	-	-	-	-
Drinking water*	2288	0.34	6.41	-	-	-	-	-
Tap water	16618	0.07	0.35	1[a]	0.01	0.01	0.01	0.01
Bottled water	2380	0.20	0.65	2[a]	0.00	0.00	0.00	0.00
Water ice	1	0.00	0.50	-	-	-	-	-
Herbs, spices and condiments*	46	54.3	54.9	-	-	-	-	-
Herbs	554	42.4	45.4	2[a]	234	234	46.0	421
Spices	881	87.5	92.8	1[a]	69.0	69.0	69.0	69.0
Herb and spice mixtures	142	54.5	67.7	3[a,c]	30.3	30.3	30.0	31.0
Seasoning or extracts	183	17.9	21.5	-	-	-	-	-
Condiment	303	11.3	14.7	2[c]	15.0	15.0	10.0	20.0
Dressing	87	1.97	5.03	-	-	-	-	-
Chutney and pickles	8	10.1	10.1	-	-	-	-	-
Savoury sauces	64	8.14	10.5	-	-	-	-	-
Flavourings or essences	91	12.4	21.5	-	-	-	-	-
Baking ingredients	161	11.7	14.7	-	-	-	-	-
Food for children*	45	14.2	14.8	1[a]	1.90	1.90	1.90	1.90
Infant formulae powder	542	2.43	4.91	4[a]	3.40	3.40	2.10	5.30
Infant formulae liquid	40	3.03	4.38	-	-	-	-	-
Follow-on formula powder	512	3.56	4.82	-	-	-	-	-
Follow-on formula liquid	58	1.00	1.40	-	-	-	-	-
Cereal-based food for children	1647	11.9	12.6	5[a]	24.0	24.0	7.60	32.0
Ready-to-eat meal for children	1350	4.34	7.03	2[a]	18.0	18.0	13.0	23.0
Dairy products for children	19	4.55	8.96	-	-	-	-	-
Juice and herbal tea for children	44	2.96	5.42	-	-	-	-	-

European data (EFSA 2012)				Norwegian data				
		µg/kg ww			µg/kg ww			
	N	Mean LB	Mean UB	N	Mean LB	Mean UB	Min	Max
Special nutritional products*	56	13.4	19.8	-	-	-	-	-
Food for weight reduction	27	24.6	25.3	-	-	-	-	-
Dietary supplements	1351	72.3	76.6	-	-	-	-	-
Algal formulations**	413	1514	1515	-	-	-	-	-
Food for sports people	31	44.3	52.9	-	-	-	-	-
Dietetic foods for diabetics	183	18.6	20.2	-	-	-	-	-
Food for medical management	20	22.5	23.4	-	-	-	-	-
Composite food*	80	4.32	19.0	-	-	-	-	-
Cereal-based dishes	66	11.3	16.6	3[a]	26.7	26.7	12.0	49.0
Rice-based meals	21	57.1	60.4	-	-	-	-	-
Potato based dishes	2	11.0	11.0	-	-	-	-	-
Beans-based meals	16	1.44	26.7	-	-	-	-	-
Meat-based meals	502	5.59	8.63	2[a]	2.15	2.90	<LOQ	4.30
Fish and seafood meals	113	23.7	25.3	27[a,l]	14.1	14.1	2.80	40.0
Vegetable-based meals	7	0.67	25.2	-	-	-	-	-
Egg-based meals	8281	1.27	5.39	1[a]	4.90	4.90	4.90	4.90
Mushroom-based meals	791	344	345	-	-	-	-	-
Ready to eat soups	223	8.20	12.1	-	-	-	-	-
Prepared salads	109	13.9	32.5	-	-	-	-	-
Snacks, desserts, other foods*	1	0.00	20.0	-	-	-	-	-
Snack food	587	26.8	27.2	6[a]	39.7	39.7	25.0	59.0
Ices and desserts	659	3.62	4.59	5[a]	3.20	3.80	<LOQ	9.30
Other non-classifiable foods	256	19.0	37.0	-	-	-	-	-

[*]FoodEx level 2 (EFSA, 2011b), "Fish and seafood" includes data for food items not defined in the following rows of this category, i.e. fish liver and brown meat from crabs which are detailed in Tables A4 and A5, respectively, [**]FoodEx level 3 (EFSA, 2011b), [a]NILU, 2011, limit of quantification, LOQ=5 µg/kg ww; [b]NILU, 2012, LOQ= 1 µg/kg ww, [c]Norwegian Food Safety Authority, 2014, LOQ=5 µg/kg dw; [d]Salbu et al., 2013, LOQ not given; [e]Alne and Gjærstad, 1998, LOQ=10 µg/kg dw, [f]Norwegian Veterinary Institute, 2012, LOQ=1 µg/kg ww, [g]NIFES, 2009b, LOQ= 10 µg/kg dw, [h]NIFES, 2013c, LOQ=5 µg/kg dw; NIFES, 2013d, LOQ=1 µg/kg ww; NIFES, 2014b, LOQ=10 µg/kg dw; NIFES, 2008a, LOQ=10 µg/kg dw; NIFES, 2013e, LOQ=10 µg/kg dw; NIFES, 2013f, LOQ=5 µg/kg dw; Julshamn et al., 2013a, LOQ=5 µg/kg dw; Julshamn et al., 2013b, LOQ=2 µg/kg ww; NIFES, 2010c, LOQ=10 µg/kg dw; Frantzen et al., 2015, LOQ=10 µg/kg dw; NIFES, 2013g, LOQ=10 µg/kg dw; NIFES, 2010d, LOQ=10 µg/kg dw; NIFES, 2011b, LOQ=10 µg/kg dw; NIFES, 2014a, LOQ=1 µg/kg ww; NIFES web page "Sjømatdata", 2015, [i]NIFES, 2007, LOQ=10 µg/kg dw; NIFES, 2011b, LOQ=10 µg/kg dw; NIFES, 2008b, LOQ=10 µg/kg, [j]NIFES, 2012a, LOQ=10 µg/kg dw; NIFES, 2013h, LOQ=10 µg/kg dw, [k]NIFES, 2010b, LOQ=10 µg/kg dw, [l]NIFES, 2009a, LOQ=10 µg/kg dw, [m]NIVA, 2012, LOQ=1 µg/kg ww, [n]NIFES, 2012b, LOQ=5 µg/kg dw; NIFES, 2013a, LOQ not given; NIFES, 2013b, LOQ=5 µg/kg dw, [o]Johansen, 2010, LOQ not given; [#]Not included analyses from Alne and Gjærstad (1998) on carrots and potatoes from areas with alum shale. Carrots mean (UB) in alum shale = 24 µg/kg, potatoes mean (UB) in alum shale = 25 µg/kg. [£]Only liver from chicken, pork and cattle are included since these are the commercial used offal products. If liver from other animals (sheep and game) where included (n=148) Cd mean=170 µg/kg. If kidneys and liver from all animals where included (n=289) Cd mean=558 µg/kg. [§]LB does not include 108 fishes caught north of Saltenfjorden due to lacking data about LOQ,
[¥]"Crustaceans" including white crab meat from Paralithodes camtschaticus and Cancer pagurus, which is detailed in Table A5, [€]dishes based on minced fish meat.

Occurrence of cadmium in cereals/cereal products and oil seeds in Norway

Table A-2 Cadmium levels in cereals/cereal products and oil seeds in Norway, given as lower bound (LB) and upper bound (UB) mean µg/kg wet weight (ww)

Food item	N	Mean µg/kg ww		Minimum µg/kg ww	Maximum µg/kg ww
		LB	UB		
Cereal products					
Course bread[1]	4	43.8	43.8	36.0	51.0
Medium course bread[1]	2	35.5	35.5	33.0	38.0
Fine bread[1]	3	29.7	29.7	24.0	34.0
Rolls[1]	4	32.8	32.8	28.0	38.0
Crisp bread and flatbread[1]	6	23.0	23.0	6.40	31.0
«Lomper»[1], tortillas[2]	4	24.3	24.3	10.0	37.0
Tacoshell/tubs[2]	2	0.00	4.50	<LOQ	4.5
Whole rye flour[1]	2	28.0	28.0	18.0	37.0
Wheat flour, whole/fine[1,3]	3	39.0	39.0	10.0	58.0
Oat bran[1,3]	1	16.0	16.0	16.0	16.0
Wheat bran[3]	4	74.0	74.0	11.0	101
«Regal solsikkebrød» (bread mix)[1]	1	73.0	73.0	73.0	73.0
Rolled oats[1,3]	8	24.0	24.0	14.0	44.0
Müsli/cereals[1,3]	7	32.0	32.0	18.0	42.0
«Havrefras»[3]	1	50.0	50.0	50.0	50.0
«Weetabix»[3]	1	46.0	46.0	46.0	46.0
«Kakaokuler»[1]	1	21.0	21.0	21.0	21.0
«Honey puffs»[1]	1	107	107	107	107
Flakes[1]	2	30.0	30.0	2.10	57.0
Rice[1]	2	5.80	5.80	2.50	9.00
Pasta[1]	5	35.0	35.0	13.0	65.0
Biscuits/cookies[1]	10	26.0	26.0	5.40	39.0
Cakes[1]	5	11.0	11.0	5.60	17.0
Buns[1]	2	26.0	26.0	22.0	30.0
Cake mix[1]	7	16.0	16.0	1.30	30.0
Total, all cereal products	**88**	**29.9**	**29.9**	1.30	107
Oil seeds					
Sunflower seed	12	255	255	60.0	580
Sesame seed	1	15.0	15.0	15.0	15.0
Pumpkin seed	1	12.0	12.0	12.0	12.0
Flax seed	1	174	174	174	174
Total, all oil seeds	**15**	**217**	**217**	12.0	580

[1] NILU, 2011, limit of quantification, LOQ=5 µg/kg ww,

[2] Norwegian Food Safety Authority, 2014, LOQ=5 µg/kg dw

[3] NILU, 2012, LOQ= 1 µg/kg ww.

Occurrence of cadmium in Norwegian fish filet

Table A-3 Data on cadmium levels in Norwegian fish filet, given as lower bound (LB) and upper bound (UB) mean µg/kg wet weight (ww)

Fish species	N	Mean µg/kg ww LB	Mean µg/kg ww UB	Minimum µg/kg ww	Maximum µg/kg ww
Cod[1,2]	2217	2.04[14]	3.16	<LOQ	1500
Tusk[3,4,5]	44	1.10	1.60	<LOQ	11.0
Saithe[6]	1620	1.50	2.00	<LOQ	29.0
Atlantic halibut[3,7]	50	1.60	2.26	<LOQ	55.0
Greenland halibut[8]	1288	2.30	3.80	<LOQ	6.30
Redfish[3]	25	2.20	2.60	<LOQ	7.00
NVG-herring[9]	800	10.0	10.0	3.00	52.0
North sea herring[10]	862	9.00	9.00	2.00	48.0
Mackerel[11]	845	16.0	16.0	<LOQ	160
Sprat[12]	32	12.0	12.0	3.00	19.0
Salmon, farmed[13]	436	0.50	2.00	1.00	29.0
Total, all species	**8219**	**4.90[14]**	**5.51**	<LOQ	1500

[1]Julshamn et al., 2013a, limit of quantification, LOQ=5 µg/kg dry weight (dw); Julshamn et al., 2013b, LOQ=2 µg/kg ww, [2]NIFES, 2013c, LOQ=5 µg/kg dw, [3]NIFES, 2013d, LOQ=1 µg/kg ww, [4]NIVA, 2012, LOQ= 1 µg/kg ww, [5]NIFES, 2014b, LOQ=10 µg/kg dw, [6]NIFES, 2013e, LOQ=10 µg/kg dw; NIFES, 2013f, LOQ=5 µg/kg dw; [7]NIFES, 2008a, LOQ=10 µg/kg dw; [8]NIFES, 2010c, LOQ=3 µg/kg ww; [9]Frantzen et al., 2015, LOQ=10 µg/kg dw, [10]NIFES, 2013g, LOQ=10 µg/kg dw, [11]NIFES, 2010d, LOQ=10 µg/kg dw, [12]NIFES, 2011b, LOQ=10 µg/kg dw,[13]NIFES, 2014a, LOQ=1 µg/kg ww; NIFES web page "Sjømatdata", 2015, [14]Cod caught north of Saltenfjorden (n=108) is not included in the LB estimates due to lacking data about LOQ.

Occurrence of cadmium in Norwegian fish liver

Table A-4 Cadmium levels in fish liver and in the traditional "Svolværpostei" (cod roe and liver pâté), given as lower bound (LB) and upper bound (UB) mean µg/kg wet weight (ww)

Fish liver and products	N	Mean µg Cd/kg		Minimum µg Cd/kg	Maximum µg Cd/kg
		LB	UB		
Cod liver					
North Sea[1]	434	76.0	76.0	10.0	530
North-East Arctic (Barents Sea)[2]	836	205	205	20.0	3900
Salten region[3]	23	-	414	70.0	1300
Coastal cod[1]	638	79.0	79.0	<LOQ	1300
Saithe liver[4]	1590	250	250	<LOQ	1800
Svolværpostei (cod roe and liver pâté)[5]	2	30.0	30.0	30.0	30.0

[1]Julshamn et al., 2013a, limit of quantification, LOQ=5 µg/kg dry weight (dw), [2]Julshamn et al., 2013b, LOQ=2 µg/kg ww, [3]NIFES, 2013c, LOQ=5 µg/kg dw. It was not possible to calculate LB for cod from the Salten region due to missing data, [4]data collected in Barents Sea during 2010-2013: NIFES, 2013e, LOQ=10 µg/kg dw; NIFES, 2013f, LOQ=5 µg/kg dw, [5]NIFES, 2009b, LOQ= 10 µg/kg dw.

Occurrence of cadmium in Norwegian crustaceans and bivalve molluscs

Table A-5 Cadmium (Cd) levels in crabs, bivalve molluscs and scrimps, given as mean µg/kg wet weight (ww) since all measurements were above limit of quantification

Type of seafood (tissue and location)	N	Mean µg/kg	Minimum µg/kg	Maximum µg/kg
Crabs (Cancer pagurus)				
Brown meat, south of Saltenfjorden[1]	380	2120	100	25000
White meat, south of Saltenfjorden[1]	385	110	4.00	1800
Brown meat, north of Saltenfjorden[1]	146	11200	900	45000
White meat, north of Saltenfjorden[1]	149	810	37.0	3700
King crabs (Paralithodes camtschaticus)[2]	23	20.0	1.00	260
Bivalve molluscs				
Blue mussels[3,4]	256	73.4	40.0	310
Oysters (Ostrea edulis)[4,5]	351	520	120	2300
Scallops[5]	39	280	110	750
Shrimps (peeled)[6]	2	111	33.0	189

[1]NIFES, 2012b, limit of quantification, LOQ=5 µg/kg dry weight (dw); NIFES, 2013a, LOQ not given, [2]Data from NIFES, 2013b, LOQ=5 µg/kg dw, [3]Data from NIFES, 2013h, LOQ=10 µg/kg dw, [4]Johansen, 2010, LOQ not given, [5]Data from NIFES, 2012a, LOQ=10 µg/kg dw, [6]Data from NILU, 2011, LOQ=5 µg/kg ww.

Occurrence of cadmium in Norwegian meat and offal

Table A-6 Cadmium levels in muscle, liver, and kidneys from livestock and game, given as lower bound (LB) and upper bound (UB) mean µg/kg wet weight (ww)

Tissue	N	Mean µg/kg ww		Minimum µg/kg ww	Maximum µg/kg ww
		LB	UB		
Muscle[1]					
Cattle	31	0.00	1.40	<LOQ	<LOQ
Pork	28	0.20	1.40	<LOQ	2.00
Sheep	26	1.70	2.40	<LOQ	10.3
Horse	2	23.5	23.5	15.0	32.0
Chicken	14	0.00	1.40	<LOQ	<LOQ
Moose	22	19.0	20.0	<LOQ	145
Deer	12	9.10	9.80	<LOQ	78.8
Reindeer	7	11.4	11.4	1.50	50.8
Roe deer	10	2.80	3.10	<LOQ	10.4
Liver[1]					
Cattle[1,2]	32	33.3	33.3	10.0	145
Pork	28	25.0	25.0	10.0	101
Sheep	27	253	253	33.0	690
Chicken	14	13.3	13.3	2.90	36.3
Moose	18	550	550	40.0	1850
Deer	12	100	100	20.0	210
Reindeer	7	600	600	300	1300
Roe deer	10	110	110	20.0	210
Kidney[1]					
Cattle	31	220	220	40.0	900
Pork	29	97.0	97.0	43.0	338
Sheep	27	1281	1281	51.0	4993
Chicken	9	20.6	20.8	<LOQ	64.4
Moose	18	2800	2800	500	12400
Deer	11	800	800	100	2400
Reindeer	6	4400	4400	4000	5000
Roe deer	10	600	600	100	2200

[1]Surveillance data, the Norwegian Veterinary Institute, 2012, limit of quantification, LOQ, 1 µg/kg ww, [2]One sample from NILU, 2011, LOQ=5 µg/kg ww.