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Environmental Protection Agency

Survey of cadmium and cadmium compounds

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Review and survey of cadmium and cadmium compounds

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Sources must be acknowledged.

Content

Preface

The Danish Environmental Protection Agency's List of Undesirable Substances (LOUS) is intended as a guide for enterprises. It indicates substances of specific concern due to the actual consumption in Denmark and for which the use should be reduced or eliminated completely. The first list was published in 1998 and updated versions have been published in 2000, 2004 and 2009. The latest version, LOUS 2009 [Danish EPA 2011] includes 40 chemical substances and groups of substances which have been classified as dangerous or identified as problematic due to other concerns. The actual criteria employed by the Danish EPA for inclusion of substances in the list include:

- Properties of concern according to the EU 'List of hazardous substances';
- Properties of concern identified using computer-based model calculations outlined in the Danish EPA's 'Advisory list for self-classification of dangerous substances' (the Self-classification list);
- PBT/vPvB substances as identified by the EU;
- Substances on the EU 'Priority list of substances for further evaluation of their role in endocrine disruption'.

Furthermore a tonnage threshold has been used. Substances used in quantities exceeding 100 tonnes per year in Denmark and fulfilling any of the above mentioned criteria have been included in LOUS 2009. For substances which are the subject of special focus in Denmark, the tonnage threshold can however be different.

Over the period 2012-2015 all 40 substances and substance groups on LOUS will be surveyed. The surveys include collection of available information on the use and occurrence of the substances, internationally and in Denmark, information on environmental and health effects, on alternatives to the substances, on existing regulation, on monitoring and exposure and information regarding ongoing activities under REACH among others.

The Danish EPA will on the basis of the surveys assess the need for any further regulation, substitution/phase out, classification and labelling, improved waste management, development of new knowledge or increased dissemination of information.

This survey concerns cadmium and cadmium compounds. The reason for including this group of substances is that it covers substances that make the use of the residual products of waste streams (flue-gas cleaning products, slag, sludge and compost) problematic and several compounds have properties of concern with regard to their harmonized classification. The substances are only subject to partial restrictions on use; other uses are also considered to be a cause for concern with regard to health and the environment [DEPA, 2011].

As the risks to the general population caused by the circulation of cadmium in agriculture and the human intake of cadmium on ionic form is of major concern , this report focuses on cadmium as an element rather than on the specific cadmium compounds.

The preparation of this report has been supervised by a steering committee consisting of:

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Summary and conclusion

Cadmium is a non-essential heavy metal which is produced mainly as a by-product from mining of zinc and to a lesser extent, lead and copper.

The knowledge available on cadmium and cadmium compounds is comprehensive and several reviews have been prepared over the years. In this context attention should be paid to the Danish Cadmium Review from 1980, the WHO assessment from 1992 and the UNEP review from 2010.

According to WHO, cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen. The kidney is regarded as the critical target organ. Cadmium accumulates primarily in the kidneys, and its biological half-life in humans is 10–35 years. This accumulation may lead to renal tubular dysfunction, which results in increased excretion of low molecular weight proteins in the urine. This effect is generally irreversible.

Cadmium is a human carcinogen by the inhalation route. Epidemiological data from occupational settings confirm the lungs as being the primary target organ. Cadmium is not considered a carcinogen by ingestion.

Aquatic fresh water and marine invertebrates are the organisms most sensitive to cadmium. The dissolved cadmium concentrations measured in some European waters (mainly rivers) exceed the threshold concentration for causing adverse effects in the aquatic ecosystem.

Food is the dominant source of cadmium exposure of humans and accounts for approximately 90 per cent of the intake of the general, non-smoking population. Cadmium occurs in all food, but agricultural crops generally account for most of the intake.

The mean intake in Denmark has been calculated at 10.8 µg/day or 0.18 µg/kg bw/day corresponding to 50% of the Tolerable Weekly Intake (TWI) value at 2.5 µg/kg bw/week (=0.36 µg/kg bw/day). This TWI value was established by the European Food Safety Agency (EFSA) in 2009. It was lowered from the previous value of 7 µg/kg bw/week based on analysis of new data. While the intake of cadmium in Denmark is at the same level as reported for the time period 1998-2003 (10 µg/day) the new TWI value means that the margin of exposure has decreased.

Cadmium in crops is due to the uptake of cadmium from soils and depends on the content of cadmium in soils as well as factors such as soil pH, salinity, humus content, crop species and varieties and the presence of zinc and other elements in the soil.

In Denmark the dominant source of cadmium to agricultural soils is the use of commercial phosphate fertilizers and atmospheric deposition originating from industrial activities and waste incineration. Both sources have been reduced significantly since the early 1980's, when the efforts to reduce cadmium pollution in Denmark started.

A Danish ban on the import and sale of cadmium was established in 1983. The ban was focused on pigments, stabilizers (in PVC) and plating, and resulted in a decrease in cadmium use for these applications. While pigments and stabilizers for PVC had been the dominating fields of consumption by 1980, the consumption pattern changed significantly during the 1980's. A growing demand for cadmium for nickel-cadmium (NiCd) batteries in Denmark and internationally has likely aided the reduced use of cadmium for pigments, stabilizers and plating.

By 1990, the dominant field of consumption was in batteries, a position maintained since then. During the 90'ties the picture of consumption has remained by and large stable. The consumption for batteries has continued to grow. New applications of cadmium marketed included "cheap silver" (silver, in which a significant part of the silver was replaced by cadmium) and photovoltaic cells. The use for "cheap silver" may reflect a low world market price for cadmium.

Photovoltaic cells (solar cells) based on cadmium-telluride and similar compounds could develop into a new significant market for cadmium. To the best of our knowledge, however, the use of cadmium for solar cells in Denmark is not significant. It must, however, be recognized that reliable Danish figures on consumption and emission to the environment dates back to before 2000 and a strong need for updated reliable figures exist.

The use of cadmium in the EU today is generally severely restricted apart from nickel-cadmium batteries. For these batteries, significant high volume uses inclusive of cordless power tools and non-portable batteries for emergency back-up etc. are still allowed. The EU strategy has been to promote collection and recycling. The results of this strategy, however, have so far not been convincing. Assessments has shown that less than 50% of the portable batteries are collected. Batteries not collected will end up in municipal waste that in Denmark is directed to waste incineration, and in the rest of Europe also to landfills.

Alternatives to cadmium are well developed and marketed for most applications. For nickel-cadmium batteries, the alternatives include nickel metal hydride (NiMH) and lithium-ion-polymer batteries. In particular Lithium-ion batteries, in particular have been developed to cover in reality all relevant applications.

The global consumption of cadmium has remained constant over the last 15 years. The dominant use of cadmium today also globally is nickel-cadmium batteries. Cadmium is produced mainly as a by-product to zinc and a reduced demand for cadmium will make it cheaper and thereby more attractive for use in products for which its use is not restricted.

In order to minimize emissions of cadmium in the longer term, it should be regarded as essential that other significant uses of cadmium (that are not designed and operated in a closed circuit) are not allowed to develop. The surplus of cadmium on the market should instead be immobilized and directed to permanent storage. This process should be considered an important challenge to the international community for the future.

Important data gaps include:

- Up to date figures on applications of cadmium and consumption by application areas in Denmark, with a special focus on cadmium in batteries.
- Up to date figures on collection and recycling activities for cadmium in Denmark.
- Up to date figures on emission of cadmium to the environment for Denmark, inclusive disposal of cadmium with waste.

Sammenfatning og konklusion

Cadmium er ikke-essentielt tungmetal, som primært udvindes som et biprodukt til zink og i mindre omfang bly og kobber.

Den eksisterende viden om cadmium og cadmiumforbindelser er omfattende og adskillige redegørelser er udarbejdet gennem årene. I denne sammenhæng er det relevant at være opmærksom på den danske cadmium redegørelse fra 1980, WHO's vurdering fra 1992 og UNEP's redegørelse fra 2010.

Ifølge WHO har cadmium giftvirkning overfor nyrene, skelettet og åndedrætssystemet og er klassificeret som kræftfremkaldende overfor mennesker. Nyrerne betragtes som det kritiske organ. Cadmium akkumulerer primært i nyrerne med en biologisk halveringstid på 10–35 år. Denne akkumulering kan påvirke nyrernes funktion og medfører øget udskillelse af lavmolekylære proteinstoffer i urinen. Dette er generelt en irreversibel påvirkning.

Cadmium er kræftfremkaldende ved indånding. Arbejdsmiljøundersøgelser bekræfter at lungerne er det kritiske organ i denne sammenhæng. Cadmium betragtes ikke som kræftfremkaldende ved indtagelse af føde- og drikkevarer.

Vandlevende hvirvelløse dyr er de organismer, som er mest følsomme overfor cadmium. I visse Europæiske vandområder (især floder) overskrider koncentrationen af opløst cadmium de niveauer, hvor cadmium medfører påvirkning af akvatiske økosystemer.

Føden er den dominerende kilde til cadmiumpåvirkning af mennesker og er ansvarlig for ca. 90% af indtaget hos den del af den almindelige befolkning, der ikke ryger. Cadmium er til stede i alle former for fødevarer, men grønsager og andre afgrøder fra landbruget er ansvarlig for størsteparten af indtaget.

Middelindtaget i Danmark er beregnet til 10.8 µg/day or 0.18 µg/kg kropsvægt/dag svarende til 50% af værdien for det tolerable ugentlige indtag (TWI) på 2.5 µg/kg kropsvægt/uge (=0.36 µg/kg kropsvægt/dag). Denne TWI værdi blev fastlagt af EFSA (the European Food Safety Agency) i 2009. Den tidligere værdi var på 7 µg/kg kropsvægt/uge, men EFSA sænkede værdien på baggrund af nye data. Mens indtaget af cadmium i Danmark på sammen niveau som tidligere rapporteret for perioden 1998-2003 (10 µg/dag) betyder den nye TWI værdi, at sikkerhedsmargenen er blevet mindre.

Afgrøder optager cadmium fra jorden. Optaget afhænger af indholdet af cadmium i jorden og faktorer som pH, indholdet af salte og humus, de specifikke afgrøder og tilstedeværelsen af zink og andre grundstoffer.

De dominerende kilder til tilførsel af cadmium til landbrugsjorden i Danmark er brugen af fosforholdig handelsgødning samt atmosfærisk nedfald stammende fra industrielle aktiviteter og affaldsforbrænding. Begge kilder er reduceret væsentligt sinde starten af 1980'erne, hvor indsatsen for at reducere cadmiumforureningen i Danmark begyndte.

Et dansk forbud mod import og salg af cadmium blev indført i 1983. Forbuddet var fokuseret på pigmenter, stabilisatorer (i PVC) og overfladebehandling af jern og stål. Dette forbud skabte en udvikling væk fra brugen af cadmium til disse formål. Mens pigmenter og stabilisatorer i plast havde været de dominerende anvendelsesområder omkring 1980, skiftede billedet meget i løbet af

1980'erne. En voksende efterspørgsel efter cadmium til NiCd batterier i Danmark og internationalt var sandsynligvis en stærk støtte til den reducerede brug af cadmium for pigmenter, stabilisatorer og overfladebehandling.

Omkring 1990 var batterier blevet den dominerende anvendelse. Denne position er fastholdt siden da. Gennem 1990'erne er forbrugsmønstret i det store og hele forblevet uændret. Der er sket en forsat øgning af forbruget af batterier. Af nye anvendelsesområder for cadmium kan nævnes solceller og "billigt sølv"(sølv, hvor en væsentlig del af sølvet er erstattet af cadmium).

Fremkomsten af "billigt sølv" kan antages at være en konsekvens af en lav verdensmarkeds pris for cadmium.

Solceller baseret på cadmium-tellur and tilsvarende forbindelser er et område, der kunne udvikle sig til væsentligt nyt marked for cadmium. Så vidt vides er brugen af cadmium til solceller i Danmark uvæsentlig. Det må dog erkendes, at de seneste danske oplysninger om forbrug og emission til omgivelserne i Danmark stammer fra før år 2000 og at der er et stærkt behov for pålidelige opdaterede oplysninger.

Brugen af cadmium i Europa i dag er generelt stramt reguleret bortset fra NiCd batterier. For disse batterier er væsentlige anvendelser med et højt forbrug stadig tilladte. Disse anvendelser omfatter batteridrevet håndværktøj og ikke-bærbare batterier til nødstrømsanlæg. EU's strategi været at fremme indsamling og genanvendelse. Resultatet af denne strategi har dog ikke været overbevisende, idet det er vurderet, at mindre end 50% af de bærbare batterier indsamles. Batterier, der ikke indsamles vil ende i husholdningsaffald, som i Danmark føres til affaldsforbrænding og i det øvrige Europa også til deponering.

Alternativer til cadmium er veludviklede og markedsført for de fleste anvendelser. For NiCd batterier omfatter alternativerne både nikkel-metalhydrid (NiMH) and lithium-ion-polymer batterier. Særligt lithium-ion batterier er udviklet til at dække i realiteten alle relevante anvendelser.

Det globale forbrug af cadmium er forblevet konstant gennem de seneste 15 år. Den dominerende anvendelse for cadmium i dag, også globalt set, er NiCd-cadmium batterier. I denne sammenhæng er det vigtigt at være opmærksom på, at cadmium produceres som et biprodukt til zink. Reduceret efterspørgsel efter cadmium vil derfor blot sænke prisen på cadmium og gøre det økonomisk attraktivt at bruge cadmium i produkter, hvor brugen af cadmium ikke er begrænset eller forbudt.

Med henblik på at minimere emissionerne af cadmium på længere sigt, må det betragtes som essentielt at andre væsentlige anvendelser (som ikke er designet til at fungere i et lukket kredsløb) ikke får lov til at udvikle sig. Cadmium, som er i overskud på markedet, bør i stedet immobiliseres og bortskaffes til permanent opbevaring. Dette bør betragtes som en vigtig opgave for det internationale samfund i fremtiden.

Væsentlige databehov omfatter:

- Opdaterede oplysninger om cadmiums anvendelser og forbruget fordelt på anvendelsesområder, især fokuseret på cadmium i batterier.
- Opdaterede oplysninger om indsamling og genanvendelse af cadmium i Danmark.
- Opdaterede oplysninger om emissioner af cadmium til omgivelserne i Danmark, herunder cadmium bortskaffet med affald.

1. Introduction to the substance group

1.1 Definition of the substance group

The substance group covers metallic cadmium and all cadmium compounds. However, as stated in the preface, this report is focused on cadmium as an element rather than on its specific compounds.

1.2 Substances included

Table 1 includes a list of substances which:

- have been registered under REACH or are intended to be registered by 2013, and/or
- are registered in the Danish Product Register with a total import and production of more than 0.001 t/y.

The table indicates the cadmium and cadmium compounds which are imported to or produced in the EU at the highest tonnage, and the substances included in mixtures imported into or produced in Denmark. The figures presented do, however, do not cover cadmium and cadmium compounds incorporated in articles imported to the EU and Denmark. In this context is noted that the use of cadmium in nickel-cadmium batteries account for 80% or more of the total consumption of cadmium. Reference is made to chapter regarding manufacture and uses.

Registered substances: Substances manufactured or imported at 1000 tonnes or more per year; carcinogenic, mutagenic or toxic to reproduction substances manufactured or imported above 1 ton per year, and substances dangerous to aquatic organisms or the environment manufactured or imported above 100 t/y (deadline for registration was 30 November 2010).

Intentions 2013: The deadline for registration of substances manufactured or imported at 100-1000 tonnes per year is 31 May 2013. The column indicates substances for which companies have expressed their intentions for registration.

Substances registered in the Danish Product Register: The registration applies to hazardous chemical products that are produced or imported for industrial use in quantities of 100 kg or more per year.

According to the Danish Working Environment Authority, the following products are notifiable:

- Substances and materials that are classified as hazardous under the Danish Ministry of the Environment's regulations (now replaced by the CLP Regulation).
- Substances and materials assigned an occupational exposure limit in the Working Environment Agency list of Limit Values for Substances and Materials.
- Materials that contain 1% or more of a substance that has been assigned an occupational exposure limit in the Working Environment list of Limit Values for Substances and Materials.
- Materials containing 1% or more of a substance classified as a health or environmental hazard according to the Danish Ministry of the Environment's regulations.

TABLE 1
IDENTIFIED SUBSTANCES WITHIN THE SUBSTANCE GROUP

CAS No	EC No	Substance name *1	Registered, tonnage band (t/y) *2	Intention 2013 *3	Danish Product Register Tonnage, t/y *4
513-78-0	208-168-9	Cadmium carbonate	100-1.000		
1306-19-0	215-146-2	Cadmium oxide	1,000-10,000		0.001-0.01
1306-23-6	215-147-8	Cadmium sulphide	10-100		
7440-43-9	231-152-8	Cadmium	1,000-10,000		0.1-1.0
8048-07-5	232-466-8	Cadmium zinc sulfide yellow		X	
10108-64-2	233-296-7	Cadmium chloride	1-10		
10124-36-4	233-331-6	Cadmium sulphate	Intermediate Use Only		
10325-94-7	233-710-6	Cadmium nitrate	100-1.000		
21041-95-2	244-168-5	Cadmium hydroxide	1,000-10,000		
58339-34-7	261-218-1	cadmium sulfose-lenide red		X	
69011-69-4	273-707-7	Cadmium, dross	Intermediate Use Only		
69012-21-1	273-721-3	Wastewater, cadmium sulfate electrolytic, acid	Intermediate Use Only		
91053-44-0	293-309-7	Leach residues, cad-mium cake	Intermediate Use Only		
102184-95-2	310-077-5	Silicic acid, zirconium salt, cadmium pig-ment-encapsulated		X	

*1 Indicates the names used in the registration or the list of 2013 intentions.

*2 Total tonnage registered is indicated in the lists of registered substances at ECHA's website (ECHA, 2012b). For substances indicated as "Intermediate use only" no tonnage band is reported.

*3 Included in the list of substances that companies have informed ECHA they intend to register by the 2013 REACH registration deadline. The list is based on responses to a survey ECHA conducted. 31 May 2013 is the deadline for industry to register all phase-in substances manufactured or imported in the EU at or above 100 tonnes a year.

*4 Tonnage indicates the registered import + manufacturing in the Danish Product Register July 2012.

1.3 Function of the substances for main application areas

The function of cadmium and cadmium compounds varies among the different applications. In the following a brief is presented overview focusing on the most important applications [DEPA 1980; DEPA 1994; Drivsholm *et al.* 2000]:

In NiCd batteries, cadmium functions as the battery anode together with a cathode of NiO and an electrolyte of potassium hydroxide.

Cadmium as a metal forms alloys with other metals and is often used to improve the characteristics (tensile and fatique strength, hardness) of these metals (copper wires, lead sheets, zinc anodes) or may replace more costly metals (e.g. replacement of silver in "cheap silver"; such silver has been measured to contain up to 30% cadmium [Drivsholm *et al.* 2000]).

Cadmium metal and cadmium oxide is used for cadmium plating of iron and steel, due to good corrosion resistance, non-voluminous corrosion products, good solderability and electrical conductivity as well as a high mechanical flexibility of cadmium.

Cadmium sulphide and cadmium selenide are insoluble compounds that may be used as pigments in many materials including plastic, ceramics, paint, etc. They provide warm brilliant colours in the range of yellow, orange, red and reddish brown and may be combined with other pigments to form a wide range of different colours.

Cadmium stearates and similar organic salts may be used as heat and UV stabilizers in PVC and similar plastics.

Cadmium telluride and cadmium sulphide may be used as semiconductor layers in solar cells.

Nanoparticles of e.g. cadmium oxide are being marketed, but are to the best of our knowledge still in the development process. Possible applications for such particles are claimed to include photovoltaic cells, flame retardants in coatings, plastics and textiles and in certain alloy and catalyst applications [AE 2012; IIAI 2009].

1.4 Data collection strategy

For cadmium a large number of reports and assessments are available from Danish authorities as well as internationally. The historic use of cadmium in Denmark, emissions to the environment and environmental and health fate and effects are well described. A long list of authoritative international documents including UNEPs global cadmium review, EUs risk assessments, WHO assessments etc. are also available.

The strategy has, therefore, primarily been to reference these existing authoritative assessments in this review of cadmium and cadmium compounds.

Regarding the regulatory framework, data collection has primarily been based on the Internet searching of the web sites of the relevant institutions supported to the extent necessary by direct contact with specialists and authorities.

2. Regulatory framework

This chapter gives an overview of how cadmium and cadmium compounds are addressed in existing and forthcoming EU and Danish legislation, international agreements and eco-label criteria. The overview reflects the findings from the data search (reference is made to data collection strategy in Section 1.4).

For readers not used to dealing with legislative issues, Appendix 1 provides a brief overview of and connections between legislatives instruments in EU and Denmark. The appendix also gives a brief introduction to chemicals legislation, explanation for lists referred to in chapter 2, as well as a brief introduction to international agreements and the aforementioned eco-label schemes.

2.1 EU and Danish legislation

This section first lists existing legislation addressing cadmium and cadmium compounds and then gives an overview of on-going activities, focusing on which substances are in the pipeline in relation to various REACH provisions.

2.1.1 Existing legislation

Table 2 gives an overview of the main pieces of existing legislation addressing cadmium and cadmium compounds. For each area of legislation, the table first list applicable EU legislation and its possible transposition into Danish law and/or other national rules. Cadmium may be mentioned in other legal instruments (e.g. defining commodity groups for statistics).

The following table lists the main instruments regulating the use and disposal of cadmium and cadmium compounds. As can be seen, cadmium and cadmium compounds are regulated through a range of cross-cutting chemicals legislation (incl. numerous restrictions), as well as sector-specific (e.g. food, feed, cosmetics, electronics, toys) and media specific (e.g. air, sludge, water) legislation.

TABLE 2
DANISH AND EU LEGISLATION SPECIFICALLY ADDRESSING CADMIUM AND CADMIUM COMPOUNDS

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
REGULATION ADDRESSING PRODUCTS	
Regulation No 1907/2006 (EC) on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	REACH Annex XVII (consolidated version of 01.06.2012): For the purpose of this entry, the codes and chapters indicated in square brackets are the codes and chapters of the tariff and statistical nomenclature of Common Customs Tariff as established by Council Regulation (EEC) No 2658/87 (*). Cadmium , CAS No 7440-43-9 , EC No 231-152-8 and its compounds: 1. Shall not be used in **mixtures and articles produced from synthetic organic polymer**s (hereafter referred to as plastic material) such as: — polymers or copolymers of vinyl chloride (PVC) [3904 10] [3904 21] — polyurethane (PUR)

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
	[3909 50] — low-density polyethylene (LDPE), with the exception of low-density polyethylene used for the production of coloured masterbatch [3901 10] — cellulose acetate (CA) [3912 11] — cellulose acetate butyrate (CAB) [3912 11] — epoxy resins [3907 30] — melamine-formaldehyde (MF) resins [3909 20] — urea-formaldehyde (UF) resins [3909 10] — unsaturated polyesters (UP) [3907 91] — polyethylene terephthalate (PET) [3907 60] — polybutylene terephthalate (PBT) — transparent/general-purpose polystyrene [3903 11] — acrylonitrile methylmethacrylate (AMMA) — cross-linked polyethylene (VPE) — high-impact polystyrene — polypropylene Mixtures and articles produced from plastic material shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,01 % by weight of the plastic material. By way of derogation, the second subparagraph shall not apply to articles placed on the market before 10 January 2012. The first and second subparagraphs apply without prejudice to Council Directive 94/62/EC (*) and acts adopted on its basis. 2. Shall not be used in **paints** [3208] [3209]. For paints with a zinc content exceeding 10 % by weight of the paint, the concentration of cadmium (expressed as Cd metal) shall not be equal to or greater than 0,1 % by weight. Painted articles shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,1 % by weight of the paint on the painted article. 3. By way of **derogation**, paragraphs 1 and 2 shall not apply to articles coloured with **mixtures containing cadmium for safety reasons**. 4. By way of **derogation**, paragraph 1, second subparagraph shall not apply to: — mixtures produced from **PVC waste,** hereinafter referred to as 'recovered PVC', — mixtures and articles containing recovered PVC if their concentration of cadmium (expressed as Cd metal) does not exceed 0,1 % by weight of the plastic material in the following rigid PVC applications: (a) profiles and rigid sheets for building applications; (b) doors, windows, shutters, walls, blinds, fences, and roof gutters; (c) decks and terraces; (d) cable ducts; (e) pipes for non-drinking water if the recovered PVC is used in the middle layer of a multilayer pipe and is entirely covered with a layer of newly produced PVC in compliance with paragraph 1 above. Suppliers shall ensure, before the placing on the market of mixtures and articles containing recovered PVC for the first time, that these are visibly, legibly and indelibly marked as follows: 'Contains recovered PVC' or with the following pictogram:  In accordance with Article 69 of this Regulation, the derogation granted in paragraph 4 will be reviewed, in particular with a view to reducing the limit value for cadmium and to reassess the derogation for the applications listed in points (a) to (e), by 31 December 2017. ◄ 5. For the purpose of this entry, 'cadmium plating' means any deposit or coating of metallic cadmium on a metallic surface. Shall not be used for **cadmium plating** metallic articles or components of the articles used in the following sectors/applications: (a) equipment and machinery for:

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
	— food production [8210] [8417 20] [8419 81] [8421 11] [8421 22] [8422] [8435] [8437] [8438] [8476 11] — agriculture [8419 31] [8424 81] [8432] [8433] [8434] [8436] — cooling and freezing [8418] — printing and book-binding [8440] [8442] [8443] (b) equipment and machinery for the production of: — household goods [7321] [8421 12] [8450] [8509] [8516] — furniture [8465] [8466] [9401] [9402] [9403] [9404] — sanitary ware [7324] — central heating and air conditioning plant [7322] [8403] [8404] [8415] In any case, whatever their use or intended final purpose, the placing on the market of cadmium-plated articles or components of such articles used in the sectors/applications listed in points (a) and (b) above and of articles manufactured in the sectors listed in point (b) above is prohibited. 6. The provisions referred to in paragraph 5 shall also be applicable to **cadmium-plated articles or components** of such articles when used in the sectors/applications listed in points (a) and (b) below and to articles manufactured in the sectors listed in (b) below: (a) equipment and machinery for the production of: — paper and board [8419 32] [8439] [8441] textiles and clothing [8444] [8445] [8447] [8448] [8449] [8451] [8452] (b) equipment and machinery for the production of: — industrial handling equipment and machinery [8425] [8426] [8427] [8428] [8429] [8430] [8431] — road and agricultural vehicles [chapter 87] — rolling stock [chapter 86] — vessels [chapter 89] 7. However, the **restrictions in paragraphs 5 and 6 shall not apply to**: — articles and components of the articles used in the aeronautical, aerospace, mining, offshore and nuclear sectors whose applications require high safety standards and in safety devices in road and agricultural vehicles, rolling stock and vessels, — electrical contacts in any sector of use, where that is necessary to ensure the reliability required of the apparatus on which they are installed. 8. Shall not be used in **brazing fillers** in concentration equal to or greater than 0,01 % by weight. Brazing fillers shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,01 % by weight. For the purpose of this paragraph brazing shall mean a joining technique using alloys and under- taken at temperatures above 450 °C. 9. By way of derogation, **paragraph 8 shall not apply** to brazing fillers used in defence and aerospace applications and to brazing fillers used for safety reasons. 10. Shall not be used or placed on the market if the concentration is equal to or greater than 0,01 % by weight of the metal in: (i) metal beads and other metal components for **jewellery** making; (ii) metal parts of jewellery and imitation jewellery articles and hair accessories, including: — bracelets, necklaces and rings, — piercing jewellery, — wrist-watches and wrist-wear, — brooches and cufflinks.

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
	11. By way of derogation, **paragraph 10 shall not apply** to articles placed on the market before 10 December 2011 and jewellery more than 50 years old on 10 December 2011.
Regulation (EC) No 689/2008 the European Parliament and of the Council of 17 June 2008 concerning the export and import of dangerous chemicals	Cadmium and its compounds included in list of chemicals subject to export notification procedure (implementation of the PIC-procedure in EU - reference is made to the Rotterdam Convention).
Regulation (EU) No 649/2012 of the European Parliament and of the Council of 4 July 2012 concerning the export and import of hazardous chemicals	Cadmium and its compounds included in list of chemicals subject to export notification procedure (implementation of the PIC-procedure in EU -reference is made to the Rotterdam Convention). The regulation replaces Regulation (EC) No 689/2008 with effect as of 1 March 2014.
Regulation (EC) No 1223/2009 of the on cosmetic products **Danish Statutory Order: Bekendtgørelse om kosmetiske produkter BEK nr 422 af 04/05/2006 (Kosmetikbekendtgørelsen)**	Cadmium and its compounds included in list of substances prohibited in cosmetic products
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) [RoHS Directive] **Danish Statutory Order; *Bekendtgørelse om begrænsning af import og salg samt fremstilling til eksport inden for EU af elektrisk og elektronisk udstyr, der indeholder visse farlige stoffer* BEK nr 284 af 24/03/2011**	New electrical and electronic equipment put on the market shall not contain cadmium in concentrations over 0.01 w% in electrical equipment. Exceptions are (exemption number in brackets): (8a) Cadmium and its compounds in one shot pellet type thermal cut-offs (expires 1/1-2012) (8b) Electrical contacts (13b) filter glasses and glasses used for reflectance standards (21) printing inks for the application of enamels on glasses, such as borosilicate and soda lime glasses (30) Cadmium alloys as electrical/mechanical solder joints to electrical conductors located directly on the voice coil in transducers used in high-powered loudspeakers with sound pressure levels of 100 dB (A) and more (38) Cadmium and cadmium oxide in thick film pastes used on aluminium bonded beryllium oxide (39) Cadmium in colour converting II-VI LEDs (< 10 µg Cd per mm 2 of light-emitting area) for use in solid state illumination or display systems (Expires on 1 July 2014) (40) Cadmium in photoresistors for analogue optocouplers applied in professional audio equipment (expires 31 December 2013)
Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles [ELV Directive] **Danish Statutory Order:**	Prohibits the use of cadmium in materials and components of vehicles in concentrations above 0.05 mg/kg. Specific exemptions (in force by Aug 2012): (16) Batteries for electrical vehicles (As spare parts for vehicles put on the market before 31 December 2008) Import, sale and production of products with concentrations over 0.01 w% within EU and EFTA

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
Bekendtgørelse om begrænsning af import, salg samt fremstilling til eksport inden for EU og til EFTA-lande af person- og varebiler m.v., der indeholder visse farlige stoffer **BEK nr 1257 af 11/12/2008**	countries Exceptions in appendix 1 of the statutory order.
Council Directive 88/378/EEC on the approximation of the laws of the Member States concerning the safety of toys **Danish Statutory Order** ***Bekendtgørelse om sikkerhedskrav til legetøj og produkter, som på grund af deres ydre fremtræden kan forveksles med levnedsmidler*** **BEK nr 1116 af 12/12/2003 (Legetøjsbekendtgørelsen)**	Bioavailability of cadmium resulting from the use of toys must not, as an objective, exceed the following levels per day: 0.6 µg/day. Part of this Directive was repealed in July 2011. The Directive is to be completely repealed by 20 July 2013 - please see below. Part of this statutory order is repealed by July 2011. The directive is completely repealed by 20 July 2013 - please see below.
Directive 2009/48/EC relating to toy safety **Danish Statutory Order:** ***Bekendtgørelse om sikkerhedskrav til legetøjsprodukter*** ***BEK nr 13 af 10/01/2011***	Limit values for cadmium in toys (Commission Directive 2012/7/EU of 2 March 2012 to be adopted by 2o Jan. 2013 at the latest): - in dry, brittle, power-like or pliable toy material: 1.3 mg/kg - in liquid or sticky toy material: 0.3 mg/kg - in scrapped-off toy material: 17 mg/kg Directive 88/378/EEC, except Article 2(1) and Part 3 of Annex II, is repealed with effect from 20 July 2011. Article 2(1) thereof and Part 3 of Annex II thereto are repealed with effect from 20 July 2013. By 31 Aug 2012 the Danish Statutory order still included old limit values: - in dry, brittle, power-like or pliable toy material: 1.5 mg/kg - in liquid or sticky toy material: 0.5 mg/kg - in scrapped-off toy material: 23 mg/kg Statutory Order No. 1116 of 12. December 2003 is partly repealed by 20 July 2011. §4 item 1.1 and annex 2, part II, item 3 are repealed 20 July 2013.
Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators **Danish Statutory orders:**	Prohibition of portable batteries or accumulators, including those incorporated into appliances, that contain more than 0,002 % of cadmium by weight. The definition of portable battery or accumulator' excludes industrial batteries or accumulators and automotive batteries or accumulators. Member States shall ensure that: (a) producers or third parties set up schemes using best available techniques, in terms of the protection of health and the environment, to provide for the treatment and recycling of waste batteries and accumulators; and (b) all identifiable batteries and accumulators collected in accordance with Article 8 of this Directive or with Directive2002/96/EC undergo treatment and recycling through schemes that comply, as a minimum, with Community legislation, in particular as regards health, safety and waste management. However, Member States may, in accordance with the Treaty, dispose of collected portable

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
Bekendtgørelse om import og salg samt eksport af batterier og akkumulatorer **BEK nr 943 af 23/09/2008 - regarding restriction on the use**	batteries or accumulators containing cadmium, mercury or lead in landfills or underground storage when no viable end market is available. Member States may also, in accordance with the Treaty, dispose of collected portable batteries or accumulators containing cadmium, mercury or lead in landfills or underground storage as part of a strategy to phase out heavy metals which, on the basis of a detailed assessment of the environmental, economic, and social impacts, shows that this disposal option should be preferred over recycling Batteries, accumulators and button cells containing more than 0,0005 % mercury, more than 0,002 % cadmium or more shall be marked with the chemical symbol for cadmium: Cd
Bekendtgørelse om batterier og akkumulatorer og udtjente batterier og akkumulatorer **BEK nr 1186 af 07/12/2009 - regarding recycling of the batteries**	Recycling processes shall achieve the following minimum recycling efficiencies: recycling of 75 % by average weight of nickel-cadmium batteries and accumulators, including recycling of the cadmium content to the highest degree that is technically feasible while avoiding excessive costs; Out of scope of the Directive: (a) equipment connected with the protection of Member States' essential security interests, arms, munitions and war material, with the exclusion of products that are not intended for specifically military purposes; (b) equipment designed to be sent into space.
Commission Regulation (EU) No 1103/2010 establish rules as regards capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators.	Establish rules as regards capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators.
Danish Statutory Order; ***Bekendtgørelse af lov om afgift af hermetisk forseglede nikkel-cadmium-akkumulatorer (lukkede nikkel-cadmium-batterier)*** **BEK nr 1251 af 06/12/2006**	Tax on sealed NiCd accumulators: Single cells: 6 DKK per cell Cell packs: 36 DKK/ pack, however minimum 6 DKK/cell
European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste **Danish Statutory Order** ***Bekendtgørelse om visse krav til emballager*** **BEK nr 1049 af 10/11/2011**	The sum of concentration levels of lead, cadmium, mercury and hexavalent chromium present in packaging or packaging components shall not exceed 100 ppm by weight. The concentration levels referred to in paragraph 1 shall not apply to packaging entirely made of lead crystal glass as defined in Directive 69/493/EEC (1). Danish Statutory Order stipulates in addition: Cadmium may not be added intentionally in the production of plastic boxes or pallets By derogation of the general requirements, glass packaging may be used if the sum of the substances do not exceed 250 ppm in weight, in glass packaging based on recycled glass where the substances are not intentionally added.
Danish Statutory Order: ***Bekendtgørelse om forbud mod import, salg og fremstilling af***	Manufacturing and import of products containing more that 75 mg cadmium per kg used as pigment, stabiliser or plating is prohibited. The Statutory order do not include products covered by Annex XVII to the REACH Regulation

<table>
<tr><th>Legal instrument</th><th>Requirements as concerns cadmium (includes amendments to the parent instruments)</th></tr>
<tr><td>cadmiumholdige varer
BEK nr 858 af 05/09/2009</td><td>(see above)
Besides these exemptions, the Statutory order lists a number of exemption under certain conditions:
<table>
<tr><td>Varekategorier</td><td>Vilkår for tilladelse til import, salg og fremstilling</td><td>Gyldighedsperiode</td></tr>
<tr><td>Lastbiler og busser</td><td>Anvendelse som pigment i plast</td><td>Indtil videre</td></tr>
<tr><td>Motorer og maskiner, væsentligt bestemt for erhvervsmæssig anvendelse</td><td>Anvendelse som cadmiering.
Meddelelse indgives til Miljøstyrelsen inden import eller fremstilling</td><td>Indtil videre</td></tr>
<tr><td>Brændere og ovne</td><td>Meddelelse indgives til Miljøstyrelsen inden import eller fremstilling</td><td>Indtil videre</td></tr>
<tr><td>Dele af varer, hvori tilstedeværelsen af cadmium er af afgørende betydning ud fra advarsels-/sikkerhedssynspunkter (færdselstavler, trafiksignaler, brandslukningsudstyr m.v.)</td><td>Meddelelse indgives til Miljøstyrelsen inden import eller fremstilling</td><td>Indtil videre</td></tr>
<tr><td>Keramiske varer, glasvarer, tandcement, kunstfarver, kunstværker m.m.</td><td>Anvendelse som farvepigment</td><td>Indtil videre</td></tr>
<tr><td>Musikinstrumenter</td><td>Anvendelse som cadmiering</td><td>Indtil videre</td></tr>
<tr><td>Præcisionsinstrumenter (optik, høreapparater m.v.)</td><td>Anvendelse som cadmiering</td><td>Indtil videre</td></tr>
<tr><td>Reservedele m.v. til reparation eller vedligeholdelse af cadmiumholdige varer, der er omfattet af denne bekendtgørelse, som er importeret, solgt eller fremstillet inden 1. januar 1989.</td><td>Meddelelse indgives til Miljøstyrelsen inden import eller fremstilling</td><td>Indtil videre</td></tr>
</table></td></tr>
<tr><td>Danish Statutory Order:
Bekendtgørelse om begrænsning i anvendelse af visse farlige kemiske stoffer og produkter til specielt angivne formål
BEK nr 857 af 05/09/2009</td><td>May not be used in glaze or decoration colours for use in non-commercial production of ceramic and enamel products, including glass products meant for food in concentrations above 0.002 % (weight)</td></tr>
<tr><td colspan="2">REGULATION ADDRESSING WASTE</td></tr>
<tr><td>Regulation (EC) No 1013/2006 on shipments of waste</td><td>This Regulation establishes procedures and control regimes for the shipment of waste, depending on the origin, destination and route of the shipment, the type of waste shipped and the type of treatment to be applied to the waste at its destination.
The Regulation requires i.a. that export of certain waste types (also waste intended for recovery) shall be prohibited depending on the type of waste and the country of destination.
Waste subject to export prohibition (included in Annex V) includes:
- Cadmium metal wastes and waste consisting of alloys of cadmium</td></tr>
</table>

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
	- Waste having as constituents or contaminants, excluding metal waste in massive form, cadmium and cadmium compounds - Waste zinc residues not included on List B, containing cadmium in concentrations sufficient to exhibit certain characteristics - Waste electrical and electronic assemblies or scrap containing cadmium - Waste metal cables coated or insulated with plastics containing cadmium - Clean, uncontaminated metal scrap, including alloys, in bulk finished form containing cadmium Furthermore, some of the listed wastes may contain cadmium but cadmium is not specifically mentioned (implementation of the Basel Convention in EU).
Regulation (EC) No 1418/2007 concerning the export for recovery of certain waste to certain non-OECD countries	Sets conditions for export of cadmium in waste to certain non-OECD countries
Council Directive 1999/31/EC on the landfill of waste **Danish Statutory Order: Bekendtgørelse om deponeringsanlæg BEK nr 650 af 29/06/2001**	Consolidated version of 31.12.2011 does not specifically indicate any provisions regarding cadmium Maximum cadmium concentration in ground water used for environmental assessment: 2 µg/L
Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture **Danish Statutory Orders *Bekendtgørelse om anvendelse af affald til jordbrugsformål (Slambekendtgørelsen)* BEK nr 1650 af 13/12/2006** **Bekendtgørelse om tilsyn med spildevandsslam m.m. til jordbrugsformål BEK nr 56 af 24/01/2000**	Limit value for cadmium concentration in sludge for use in agriculture: 40 mg/kg dw Limit value for amounts of cadmium added annually to agricultural land based on 10-years average: 0.15 kg/ha/year Danish Statutory order: Limit value for cadmium in sludge for use in agriculture : 0.8 mg/kg dw; 100 mg/kg total P Sets the frequency of analysis and control
Danish Statutory Order: *Bekendtgørelse om anvendelse af restprodukter og jord til bygge- og anlægsarbejder og om anvendelse af sorteret, uforurenet bygge- og anlægsaffald* BEK nr 1662 af 21/12/2010	Limit values of cadmium in residual products and earth in three categories: 1: 0-0.5 mg/kgDW and 0-2 µg/L eluate 2: >0.5 mg/kgDW and 0-2 µg/L eluate 3: >0.5 mg/kgDW and 2-40 µg/L eluate

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
Danish Statutory Order: ***Bekendtgørelse om anvendelse af bioaske til jordbrugsformål (Bioaskebekendtgørelsen)*** **BEK nr 818 af 21/07/2008**	Standard declaration applied if concentration is max 0.5 mg Cd/kg dm Use in agriculture max 0.8 g Cd/ha/year, 5 year average Use in forestry max 60 g Cd/ha per 75 year
Danish Statutory Order: ***Bekendtgørelse om anlæg, der forbrænder affald*** **BEK nr 1356 af 21/12/2011** **Transposes part of the provisions of Directive 2010/75/EU on industrial emissions**	Waste water from cleaning of flue gas: 0.05 mg/L Flue gas emission limit for cadmium: 0.05 mg/Nm^3 Flue gas emission limit from incineration of oil waste: 0.1 mg/Nm^3
Danish Statutory Order: ***Bekendtgørelse om anmeldelse og dokumentation i forbindelse med flytning af jord*** ***BEK nr 1479 af 12/12/2007 (Jordflytningsbekendtgørelsen)***	Stipulates rules for notification and documentation when soil containing cadmium above the limit values is displaced under certain conditions. Limit values: Category 1: <0,5 mg/kg Category 1: <5 mg/kg
REGULATION ADDRESSING EMISSIONS TO THE ENVIRONMENT	
Regulation (EC) No 166/2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC (PRTR Regulation)	Releases of cadmium and cadmium compounds shall be reported by operators with activities above a certain activity threshold if the releases are above a certain threshold releases: To air: 1o kg/year To water: 5 kg/year To land: 5 kg/year
Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) (Recast)	Emission values for cadmium and its compounds (expressed as Cd): Air emission limit values for waste incineration plants: 0.05 mg/Nm^3 Emission limit values for discharges of waste water from the cleaning of waste gases from co-incineration of waste: 0.05 mg/L
Danish Statutory Order: ***Bekendtgørelse om grænseværdier for udledning af cadmium med processpildevand fra visse industrianlæg*** ***BEK nr 181 af 25/03/1986***	Limit values for releases of cadmium from certain industrial sources: some metallurgical processes, manufacture of cadmium compounds, pigments, stabilisers, batteries Limit value: 0.2 mg per litre s discharged
REGULATION ADDRESSING QUALITY OF THE ENVIRONMENT	
Directive 2004/107/EC relating to arsenic, cadmium, mercury,	Establish a target value for the concentration of cadmium in ambient air: 5 ng/m^3 Require that that ambient air quality is maintained where it is good and that it is improved in

<table>
<tr><th>Legal instrument</th><th>Requirements as concerns cadmium (includes amendments to the parent instruments)</th></tr>
<tr><td>nickel and polycyclic aromatic hydrocarbons in ambient air

Danish Statutory Order:
Bekendtgørelse om vurdering og styring af luftkvaliteten
BEK nr 1326 af 21/12/2011 (Luftkvalitetsbekendtgørelsen)</td><td>other cases
Determine common methods and criteria for the assessment of concentrations of cadmium in ambient air and deposition.

Danish Statutory Order: Deadline for assessment of measure 31 December 2012.</td></tr>
<tr><td>Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy [Water framework Directive]

Danish Statutory Orders:
Bekendtgørelse om miljøkvalitetskrav for vandområder og krav til udledning af forurenende stoffer til vandløb, søer eller havet
BEK nr 1022 af 25/08/2010

Bekendtgørelse om fastsættelse af miljømål for vandløb, søer, kystvande, overgangsvande og grundvand
BEK nr 1433 af 06/12/2009

Bekendtgørelse om kvalitetskrav til miljømålinger BEK nr 900 af 17/08/2011</td><td>Cadmium included in list of priority hazardous substance.
Specific environmental quality standards (EQS) for cadmium and its compounds (depending on water hardness classes). AA: annual average; MAC: maximum allowable concentration; Unit: µg/L:

<table><tr><td>AA-EQS (2)
Inland surface waters (3)</td><td>AA-EQS (2)
Other surface Waters</td><td>MAC-EQS (4)
Inland surface waters (3)</td><td>MAC-EQS (4)
Other surface waters</td></tr><tr><td>≤ 0,08 (Class 1
0,08 (Class 2
0,09 (Class 3)
0,15 (Class 4
0,25 (Class 5)</td><td>0,2</td><td>≤ 0,45 (Class 1)
0,45 (Class 2)
0,6 (Class 3)
0,9 (Class 4)
1,5 (Class 5)</td><td>≤ 0,45 (Class 1)
0,45 (Class 2)
0,6 (Class 3)
0,9 (Class 4)
1,5 (Class 5)</td></tr></table>AA: Annual average; MAC: Max. Concentration.

Sets action levels by quality control and requirements regarding the quality of analyses</td></tr>
<tr><td>Directive 2006/118/EC on the protection of groundwater against pollution and deterioration

Danish Statutory Order:
Bekendtgørelse nr 1434 af 06/12/2009 om overvågning af overfladevand, grundvand, beskyttede områder og om naturovervågning i internationale naturbeskyttelsesområder mv.</td><td>Requires MS to consider establishing threshold values for groundwater

Establish rules for monitoring of groundwater</td></tr>
<tr><td>Directive 2006/113/EC on the</td><td>Sets quality values for shellfish waters for cadmium and other substances</td></tr>
</table>

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
quality required of shellfish waters (codified version) **Danish Statutory Order:** ***Bekendtgørelse om kvalitetskrav for skaldyrvande*** **BEK nr 38 af 19/01/2011**	
Bekendtgørelse af lov om beskyttelse af havmiljøet (Havmiljøloven) **BEK nr 929 af 24/09/2009**	Cadmium may only be found in insignificant amounts and concentrations in dredging material.
REGULATION ADDRESSING FERTILIZER, FEED AND FOOD	
Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs	Sets maximum levels for cadmium in a number of different foodstuffs. The maximum levels range from 0.05 to 3.0 mg/kg depending on foodstuff (16 groups of foodstuff)
Directive 2002/32/EC on undesirable substances in animal feed as regards lead, fluorine and cadmium **Danish Statutory Order:** ***Bekendtgørelse* 998 af 12/10/2004 om foderstoffer**	Sets maximum content of cadmium in different types of feed stuff
Bekendtgørelse om indhold af cadmium i fosforholdig gødning **BEK nr 223 af 05/04/1989**	Limit value of cadmium in phosphor-containing fertilizer: 110 mg/kg phosphorus (P)
Council Directive 84/500/EEC of 15 October 1984 on the approximation of the laws of the Member States relating to ceramic articles intended to come into contact with foodstuffs **Danish Statutory Order** ***Bekendtgørelse om fødevarekontaktmaterialer*** **BEK nr 579 af 01/06/2011**	The quantities of cadmium transferred from ceramic articles shall not exceed the limits laid down below: Category I: *0.07 mg/dm* ^{2} Category II: *0.3 mg/dm* ^{2} Category III: *0.1 mg/dm* ^{2}
Commission Directive 2003/40/EC establishing the list, concentration limits and labelling requirements for the constituents of natural mineral waters and the conditions for	Limit value of cadmium in mineral water: 0.003 mg/L

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
using ozone-enriched air for the treatment of natural mineral waters and spring waters ***Danish Statutory Order: Bekendtgørelse om naturligt mineralvand, kildevand og emballeret drikkevand*** **BEK nr 1015 af 10/12/2003 (Mineralvandsbekendtgørelsen)**	
REGULATION ADDRESSING THE WORKING ENVIRONMENT	
Council Directive 98/24/EC and amending Commission Directive 2000/39/EC	Establish indicative occupational exposure limits for chemical agents Currently no established occupational exposure limit for cadmium, but the Scientific Committee on Occupational Exposure Limits (SCOEL) has published the following recommended levels for cadmium and its inorganic compounds (SCOEL/SUM/136, February 2010): - Biological Limit Value (BLV): 2 µg Cd/g creatinine - Occupational Exposure Limit (OEL): 0.004 mg Cd/m^3
Danish Statutory Order; Bekendtgørelse om ændring af bekendtgørelse om grænseværdier for stoffer og materialer **BEK nr 1134 af 01/12/2011**	Limit value for cadmium: 0.005 mg/m^3 K (kræftfremkaldende)
Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work	Establish rules for reduction in exposure to carcinogens in the Working Environment. The rules apply to all compounds (inclusive of cadmium compounds) classified as carcinogenic in category 1 or 2.
Danish Statutory Order: ***Bekendtgørelse om foranstaltninger til forebyggelse af kræftrisikoen ved arbejde med stoffer og materialer*** ***BEK nr 908 af 27/09/2005***	Sets conditions for certain working processes with cadmium compounds above a concentration of 0.1% cadmium or cadmium compound. Actual conditions may e.g. include: Laboratory work: Working processes involving substances or materials shall only take place in closed systems or by other means preventing the release of the substances and materials so as to exclude any exposure to the effects therefrom. Other Uses: Use of the substances shall not take place without the approval of the Danish Working Environment Authority. A part of this approval is based on documentation from the applier that it is not possible to replace the material or process with a less hazardous one.
Danish Statutory order: Bekendtgørelse om arbejde med	This Executive Order applies to any work with substances and materials, including their manufacture, use and handling. The Order demands the employer to ensure that dangerous substanc-

Legal instrument	Requirements as concerns cadmium (includes amendments to the parent instruments)
stoffer og materialer med senere ændringer BEK nr 292 af 26/04/2001	es and materials at the workplace are eliminated, replaced or reduced to a minimum.

It may be noted that a draft proposal relating to cadmium in fertilisers has been prepared by the European Commission [EC2003].

2.2 Classification and labelling

Substances and mixtures placed on the market in EU shall be classified, labelled and packaged according to the CLP regulation (1272/2008/EC)

Table 3 lists the harmonised classification and labelling for cadmium and cadmium compounds according to Annex VI of the CLP Regulation. The table shows that cadmium and many cadmium compounds are classified for carcinogenic, mutagenic and/or reproductive toxicity properties (CMR substances), as well as for acute toxicity/target organ toxicity and aquatic toxicity. Differences in human health classifications for the different compounds may e.g. be ascribed to differences in solubility and bioavailability of the compounds. Similarly the lower ecotoxicity classification observed for cadmium sulphide must be ascribed to the fact that this compound is less soluble, and the cadmium ion not readily released.

Substances that have a harmonised classification as carcinogenic, mutagenic or reproductive toxicity in Cat 1A or 1B must not be used in substances or mixtures placed on the market for sale to the general public According to REACH Annex XVII.

Self-Classifications for cadmium compounds provided by companies in their C&L notifications or registration dossiers are summarized in Appendix 2. This information is registered in The Classification & Labelling (C&L) Inventory database at the website of the European Chemicals Agency (ECHA). ECHA maintains the Inventory, but does not verify the accuracy of the information (ECHA, 2012). Self-Classification largely equals the harmonized classification, but it is also evident that companies are not able to classify the compounds in question correctly in several cases.

Authorisation List / REACH Annex XIV

The Authorisation List contains all SVHC substances prioritised and recommended for inclusion in ANNEX XIV under REACH (Appendix 1). No cadmium compounds are included in the Authorisation List as of August 2012.

Ongoing activities - pipeline

Community Rolling Action Plan (CoRAP)

The Community Rolling Action Plan (CoRAP) is a tool for coordination of substance evaluation between EU member states, indicating when a given substance is expected to be evaluated and by whom (Appendix 1).

No cadmium compounds are included in the Community Rolling Action Plan (CoRAP) (ECHA, 2012) as of 3 August 2012.

TABLE 3
HARMONISED CLASSIFICATION ACCORDING TO ANNEX VI OF REGULATION (EC) NO 1272/2008 (CLP REGULATION)

Index No	International Chemical Identification	CAS No	Classification	
			Hazard Class and Category Code(s) *1	Hazard statement Code(s) *2
048-002-00-0	cadmium (non-pyrophoric) *3	7440-43-9	Carc. 1B Muta. 2 Acute Tox. 2 Repr.2 STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	H350 H341 H330 H361fd H372 H400 H410
048-011-00-X	cadmium (pyrophoric) *3	7440-43-9	Pyr. Sol. 1 Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	H250 H350 H341 H361fd H330 H372 H400 H410
048-002-00-0	cadmium oxide (non-pyrophoric)	1306-19-0	Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	H350 H341 H361fd H330 H372 H400 H410
048-003-00-6	cadmium diformate; cadmiumformate	4464-23-7	Acute Tox. 3 * Acute Tox. 3 * Carc. 2 STOT RE 2 * Aquatic Acute 1 Aquatic Chronic 1	H331 H301 H351 H373 ** H400 H410
048-004-00-1	cadmium cyanide	542-83-6	Acute Tox. 2 * Acute Tox. 1 Acute Tox. 2 * Carc. 2 STOT RE 2 * Aquatic Acute 1 Aquatic Chronic 1	H330 H310 H300 H351 H373 ** H400 H410
048-005-00-7	cadmiumhexafluorosilicate (2); cadmium fluorosilica	17010-21-8	Acute Tox. 3 * Acute Tox. 3 * Carc. 2 STOT RE 2 * Aquatic Acute 1 Aquatic Chronic 1	H331 H301 H351 H373 ** H400 H410
048-006-00-2	cadmium fluoride	7790-79-6	Carc. 1B Muta. 1B Repr. 1B	H350 H340 H360fd

			Acute Tox. 2 *	H330
			Acute Tox. 3 *	H301
			STOT RE 1	H372 **
			Aquatic Acute 1	H400
			Aquatic Chronic 1	H410
048-007-00-8	cadmium iodide	7790-80-9	Acute Tox. 3 *	H331
			Acute Tox. 3 *	H301
			Carc. 2	H351
			STOT RE 2 *	H373 **
			Aquatic Acute 1	H400
			Aquatic Chronic 1	H410
048-008-00-3	cadmium chloride	10108-64-2	Carc. 1B	H350
			Muta. 1B	H340
			Repr. 1B	H360fd
			Acute Tox. 2	H330
			Acute Tox. 3	H301
			STOT RE 1	H372
			Aquatic Acute 1	H400
			Aquatic Chronic 1	H410
048-009-00-9	cadmium sulphate	10124-36-4	Carc. 1B	H350
			Muta. 1B	H340
			Repr. 1B	H360FD
			Acute Tox. 2	H330
			Acute Tox. 3	H301
			STOT RE 1	H372
			Aquatic Acute 1	H400
			Aquatic Chronic 1	H410
048-010-00-4	cadmium sulphide	1306-23-6	Carc. 1B	H350
			Muta. 2	H341
			Repr. 2	H361fd
			STOT RE 1	H372
			Acute Tox. 4	H302
			Aquatic Chronic 4	H413
048-001-00-5	cadmium compounds, with the exception of cadmium sulphoselenide (xCdS.yCdSe), reaction mass of cadmium sulphide with zinc sulphide (xCdS.yZnS), reaction mass of cadmium sulphide with mercury sulphide (xCdS.yHgS), and other compounds specified separately.		Acute Tox. 4 *	H332
			Acute Tox. 4 *	H312
			Acute Tox. 4 *	H302
			Aquatic Acute 1	H400
			Aquatic Chronic 1	H410

1 Use of "" in connection with a hazard category (e.g. Acute Tox. 4 *) implies that the category stated shall be considered as a minimum classification.

*2 Use of "**" in connection with a hazard statement code (e.g. H373**) implies that the route of exposure is not specified.

*3 Data in [EC 2008] are not completely consistent with [ECHA 2012b]. In [ECHA 2012b] cadmium, cadmium oxide and cadmium chloride is not classified as Aquatic Acute 1 (H400).

Registry of Intentions (EU)

The 'registry of intentions' gives on overview of intensions by EU member states in relation to Annex XV dossiers. Such intentions made include harmonised classification and labelling, identification of a substance as being in the group of Substances of Very High Concern (SVHC) or a restriction related to the substance (Appendix 1).

Table 4 shows Registry of Intentions for Restriction proposals, proposals for harmonised classifications and labelling and proposals for identifying cadmium compounds as Substances of Very High Concern (SVHC).

It shows that currently there are no cadmium compounds in the pipeline for restrictions and harmonised classification and labelling, whereas there are intentions for identifying cadmium, cadmium oxide and cadmium sulphide as SVHC based on their CMR properties.

TABLE 4
CADMIUM AND CADMIUM COMPOUNDS ON THE REGISTRY OF INTENTIONS (3 AUGUST 2012)

Registry of:	CAS No	Substances	Scope	Dossier intended by	Expected date of submission:
Current SVHC intentions	7440-43-9	Cadmium	CMR	Sweden	28/01/2013
	1306-19-0	Cadmium oxide	CMR	Sweden	28/01/2013
	1306-23-6	Cadmium sulphide	CMR	Sweden	28/01/2013

2.3 International agreements

Table 5 gives an overview of how cadmium and cadmium compounds are addressed by various international agreements. Relevant international agreements include Sea conventions (OSPAR, HELCOM, Barcelona and Bucharest) together with UN-Conventions (Basel, Rotterdam and Stockholm).

It shows that cadmium is on the OSPAR priority list with intentions of reducing discharges in order to reach near-background concentrations in the OSPAR maritime area (the North-East Atlantic), whereas the HELCOM (Baltic Sea), Barcelona (Mediterranean Sea) and Bucharest (Black Sea) Conventions suggest limitations of discharge from landbased sources. HELCOM further recommends strict limitations in a number of kinds of electrical equipments and the Barcelona Convention addresses dumping from ships.

Finally, cadmium-containing waste is addressed by the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal implemented by the EU in Regulation 1013/2006 on the shipment of waste. Cadmium is not directly covered by the Rotterdam Convention on prior informed consent (the PIC-procedure), but is, however, covered by Regulation (EC) No 689/2008 implementing the Convention in the EU. Cadmium is not covered by the Stockholm Convention on POP-substances (implemented in the EU as Regulation 850/2004/EC).

TABLE 5
INTERNATIONAL AGREEMENTS ADDRESSING CADMIUM AND CADMIUM COMPOUNDS

Agreement	Substances	Requirements
OSPAR Convention	Cadmium	Included on the OSPAR list of priority substances. The Convention aims at preventing pollution of by continuously reducing discharges, emissions and losses of hazardous substances, with the ultimate aim to achieve concentrations in the OSPAR maritime area near background values for naturally occurring substances and close to zero for synthetic substances Relevant recommendations include: OSPAR Recommendation 98/1 concerning Best Available Techniques and Best Environmental Practice for the Primary Non-Ferrous Metal Industry (Zinc, Copper, Lead and Nickel Works) (recommends use of best available technologies) PARCOM Recommendation 97/2 on Measures to be Taken to Prevent or Reduce Emissions of Heavy Metals and Persistent Organic Pollutants Due to Large Combustion Plants (> 50 MWth) (recommends use of best available technologies to minimize emissions) PARCOM Recommendation 97/1 Concerning Reference Values for Effluent Discharges for Wet Processes in the Textile Processing Industry (presents discharge reference values) PARCOM Recommendation 92/4 on the Reduction of Emissions from the Electroplating Industry (recommends substitution of cadmium) PARCOM Decision 90/2 on Programmes and Measures for Mercury and Cadmium Containing Batteries (requires separate collection and disposal of cadmium batteries and promotes recycling of batteries and use of cadmium -free batteries)
HELCOM (Helsinki Convention)	Cadmium in portable batteries or accumulators	Recommends: To ban portable batteries or accumulators containing more than 0.002 % of cadmium by weight with the exception for portable batteries or accumulators intended for use in emergency and alarm systems, including emergency lighting, medical equipment or cordless power tools.
	Discharge of cadmium from land based sources	Recommends: Effective treatment of wastewater containing cadmium so that the concentration and quantity of cadmium in effluents from various industrial sources as monthly averages should not exceed the 0.2 mg/L at the point where the effluent leaves the plant.
Barcelona Convention	Cadmium and compounds	The Protocol for the protection of the Mediterranean Sea against Pollution from land-based sources and activities commits the parties to undertake to eliminate pollution deriving from land-based sources and activities, in particular to phase out inputs of the substances that are toxic, persistent and liable to bioaccumulate, as e.g. heavy met-

Agreement	Substances	Requirements
		als and their compounds.
	Wastes and other matters containing cadmium and cadmium compounds	The Protocol for the Prevention of Pollution in the Mediterranean Sea by dumping from ships and aircrafts commits the parties to prohibit dumping of wastes and other matters containing e.g. cadmium and cadmium compounds
Bucharest Convention	Cadmium and compounds	The Convention for the Protection of the Black Sea against pollution commits the contracting parties to individually or jointly take all appropriate measures in accordance with the provisions of the Convention and Protocols in force to prevent, control and to the maximum extent possible eliminate pollution of and other adverse effects on the marine environment or coastal areas of the Black Sea from land-based sources and activities. The Convention includes heavy metals and their compounds.
Basel Convention	Control of Transboundary Movements of Hazardous Wastes and Their Disposal	Set out control measures of the movements of hazardous waste incl. of waste containing cadmium between nations, and restricts transfer of hazardous waste from developed to less developed countries (non adopted). The Convention also intends to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate.

2.4 Eco-labels

The use of cadmium is generally prohibited or restricted in criteria for Eco-labels. In Appendix 3 an overview is provided on how cadmium and cadmium compounds are addressed by the EU, Nordic and German eco-labelling schemes.

As shown, the presence of cadmium and cadmium compounds is prohibited or strictly limited in the schemes for a long list of products such as plastics/coatings/coverings/building materials, dyes/pigments/additives, batteries/electronic equipment, paper packaging, furniture/textiles, tyres, cosmetics and toys.

Cadmium may either be restricted by generic requirements prohibiting the use of CMR substances in certain types of products, materials and processes, or by specific restrictions of the overall cadmium content in the final product for which the ecolabel is granted.

2.5 Summary

As further specified in the sections on environmental and human health effects, cadmium and many cadmium compounds, in particular when the cadmium ion is readily available, are known to be highly toxic to human health (incl. carcinogenic, mutagenic, toxic to reproduction) and to the environment.

This is reflected in the classification of cadmium compounds and in the extensive existing regulation of cadmium and cadmium compounds, including a range of cross-cutting chemicals legislation

(incl. numerous restrictions), as well as sector-specific (e.g. food, feed, cosmetics, electronics, toys) and media-specific (e.g. air, sludge, water) legislation. Cadmium is thus already heavily regulated, which may explain that why little effort currently appears to be put into further regulation; exceptions are that EU is considering a regulation addressing cadmium in fertilisers and some cadmium compounds are being suggested as substances of very high concern (SVHC) under REACH.

Cadmium is addressed by several international agreements addressing the marine environment (OSPAR, HELCOM, Barcelona, Bucharest) and waste (Basel); besides these, the EU has established a PIC-procedure for export of cadmium and cadmium compounds out of EU. The use of cadmium is generally prohibited or highly restricted in criteria for eco-labels as exemplified by the EU, Nordic and German eco-labels.

3. Manufacture and uses

3.1 Global manufacture and use of cadmium and cadmium compounds

UNEP [2010] has published a review of scientific information on cadmium. An extract of the summary is presented below:

"Cadmium is produced mainly as a by-product from mining, smelting and refining of zinc, and to a lesser degree as a by-product of lead and copper production. Cadmium minerals do not occur in concentrations and quantities sufficient to justify mining them in their own right. As it is a by-product of zinc mining, the production of cadmium is more dependent on zinc refining volumes than on market demand.

Cadmium is refined in several countries inclusive of China, Japan, Republic of Korea, Kazakhstan, Canada, Mexico, Russia, Germany etc.

Global cadmium production increased during the period from 1970 to 2004 from about 17,000 tonnes to about 22,000 tonnes. Over the last 15 years, global consumption has remained constant, at around 20,000 tonnes.

Major changes have taken place with regard to the geographical distribution of cadmium production from mining sources. In 1997, the production in Europe, the Americas and Asia was about the same size. Since 1997 production in Asia has increased sharply, whereas the production in Europe has decreased correspondingly. In 2004, the production in Asia was about 5 times the production in Europe.

It is estimated that recycled cadmium today accounts for 3,500 tonnes, corresponding to about 18 percent of the total global supply. Countries with significant recycling production include the United States, Sweden, France, Germany and Japan.

Cadmium is used and traded internationally as a metal and as a chemical compound in many different types of products. Cadmium is, furthermore, mobilized as a natural contaminant in other materials, e.g. in fossil fuels and phosphate fertilizers. Cadmium may also be present as a trace pollutant in recycled materials such as recycled plastics containing cadmium pigments.

An increasing part of the global cadmium consumption is used for nickel-cadmium (NiCd) batteries, which in 2005 accounted for 82 percent of the total cadmium consumption. Other major uses are: pigments for plastics, ceramics, and enamels; stabilizers for plastics, in particular polyvinyl chloride (PVC); plating on iron and steel; and as an alloying element of some lead, copper and tin alloys. Since 1990, the cadmium consumption for pigments, stabilizers, alloys and other uses has decreased significantly.

Many products in which cadmium is used intentionally are traded globally. This is the case in particular for its dominant use - NiCd batteries - but also for many applications in alloys, plastics, plating and in electronic and electrical equipment. In this context, a consequence of international trade is that products containing cadmium will be spread to consumers in countries worldwide."

3.2 Manufacture and use of cadmium and cadmium compounds in the EU

In 2009 primary cadmium production took place in six EU Member States: The Netherlands (600 t/y), Germany (500 t/y), Italy (450 t/y), Bulgaria (400 t/y), Poland (350 t/y), Romania (<100 t/y) plus Norway (200 t/y), while recycling plants are operating in France, Germany and Sweden [RPA 2010],

Cadmium in zinc ores is also mined and concentrated in EU, essentially in Ireland and Sweden, but also in lower volumes in Poland, Bulgaria, Greece and Portugal [RPA 2010].

Based on information from the International Cadmium Association (ICdA), in 2007-2008 there was an import of cadmium to the EU of 9,020 t/y, and an export from the EU of 6,900 t/y. The export was dominated by NiCd-batteries (1,600 t/y) and cadmium oxide (5,000 t/y) meant for production of batteries [RPA 2010]. The difference between the net import of cadmium to the EU of 2,120 t/y and the consumption for end uses of 1,910 t/y stated in Table 6 could be explained as cadmium disposed of as production waste in EU.

End uses in EU in 2007-2008 by application area are shown in Table 6.

About 50 t/y was used in photovoltaic cells (solar panels). RPA [2010] notes that the photovoltaics application was booming in the years before 2009 and that is was quite plausible that it would reach 100 t/y in a short time. The amount of cadmium used in thin-film CdTe modules is about 5-10 g/m². CdTe took up 2.7% of the total European photovoltaic cells market in 2006 [EPIA 2007]. Fraunhofer [2012] notes that CdTe represented 8% of the global market of photovoltaic cells in 2011.

TABLE 6
END USES OF CADMIUM IN EU IN 2007-2008 [RPA 2010]

Application	Tonnes/year	%
Batteries	1,700	89
Pigments	140	7
Plating	10	0.5
Stabilizers	0	0
Photovoltaics	50	2.6
Alloys	10	0.5
Total	1,910	100

Registered uses of cadmium and cadmium compounds by ECHA are listed in Table 7. Many of the uses listed are fairly insignificant responsible for limited consumption of cadmium.

With respect to NiCd-batteries the EU Directive 2006/66/EC restricts the uses allowed to portable batteries and accumulators intended for use in:
(a) emergency and alarm systems, including emergency lighting;
(b) medical equipment; or
(c) cordless power tools.

Furthermore, large non-portable NiCd-batteries for emergency back-up systems etc .and replacement batteries for existing electrical vehicles are not restricted by Directive 2006/66/EC.

It is noted that Danish investigations have revealed that in 2002 cordless power tools accounted for approximately 91% of the consumption of cadmium related to portable batteries and accumulators [Maag and Hansen, 2005].

TABLE 7
USES AND TONNAGE BANDS ACCORDING TO REGISTRATIONS AT ECHA'S WEBSITE (ECHA, 2012B)

CAS No	Substance	Tonnage band	Registered (identified) uses
513-78-0	Cadmium carbonate	100-1,000	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of inorganic pigments Additive for production of glass Catalysts containing cadmium carbonate Component for polymer-matrices, plastics and related preparations Use of CdCO3-containing polymers for cable protecting and isolating coatings, tube and sheet articles and molded articles Laboratory reagent
1306-19-0	Cadmium oxide	1,000-10,000	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of inorganic pigments Additive for production of glass Cadmium production by pyrometallurgy Additive in the manufacturing of electronic components Additive for production of frits CdO in electrotechnical contact material Component for polymer-matrices, plastics and related preparations Batteries/Fuel cells Electrogalvanizing and electroplating, Catalysts containing cadmium oxide Use of CdCO3-containing polymers for cable protecting and isolating coatings, tube and sheet articles and molded articles Laboratory reagent
1306-23-6	Cadmium sulphide	10-100	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of PV (photovoltaic) modules Component for production of inorganic pigments Additive in the manufacturing of electronic components Additive for production of frits Additive for production of glass Catalysts containing cadmium sulphide Cadmium production by pyrometallurgy Laboratory reagent
7440-43-9	Cadmium	1,000-10,000	Cadmium metal production by pyrometallurgy Production of chemicals Additive for production of inorganic catalysts Melting, alloying and casting

CAS No	Substance	Tonnage band	Registered (identified) uses
			Cadmium casting and rolling Wire and rods manufacturing Component for brazing products Cadmium (alloyed) powder manufacturing Use of fine powders for mechanical plating Manufacturing of Cadmium containing-alloys Electroplating Component for soldering products Powders for contact materials Use of active powders for batteries PVD/coating (physical vapour deposition)
8048-07-5	Cadmium zinc sulfide yellow	No data	No data
10108-64-2	Cadmium chloride	1-10	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of PV (photovoltaic) modules Solar panel manufacturing Electrogalvanizing and electroplating, Laboratory chemical, agent and reagent
10124-36-4	Cadmium sulphate	No data	Intermediate Component for production of inorganic cadmium compounds Laboratory reagent
10325-94-7	Cadmium nitrate	100-1,000	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of inorganic pigments Additive for production of ceramics Additive for production of glass Catalysts containing cadmium nitrate Batteries/Fuel cells Use of Cd(NO3)2-containing photographic emulsions Laboratory reagent
21041-95-2	Cadmium hydroxide	1,000-10,000	Component for production of inorganic cadmium compounds Component for production of organic cadmium compounds Component for production of inorganic pigments Cadmium production by pyrometallurgy Batteries/Fuel cells Electrogalvanizing and electroplating, Laboratory reagent
58339-34-7	Cadmium sulfose-lenide red	No data	No data
69011-69-4	Cadmium, dross	No data	Intermediate
69012-21-1	Wastewater, cadmium sulfate electrolytic, acid	No data	Intermediate
91053-44-0	Leach residues, cad-mium cake	No data	Intermediate

CAS No	Substance	Tonnage band	Registered (identified) uses
102184-95-2	Silicic acid, zirconium salt, cadmium pigment-encapsulated	No data	No data

3.2.1 Statistics on manufacture and import/export of cadmium and cadmium compounds on its own

Available statistical data on manufacture and import/export of cadmium and cadmium compounds on the EU27 level is presented in Table 8. It is noted that the EU PRODCOM database on production in Europe does not include any separate statistical activity codes for cadmium or cadmium compounds production.

TABLE 8
EU27 EXTERNAL IMPORT AND EXPORT OF CADMIUM AND CADMIUM COMPOUNDS (EUROSTAT, 2012A)

CN code	Text	Import, tonnes/year		Export, tonnes/year	
		Average 2006-2010	2011	Average 2006-2010	2011
2825 90 60	Cadmium oxide	83	91	3,157	2,227
Cadmium and articles thereof:					
8107 20 00	Unwrought cadmium; powders	3,514	3,498	1,993	2,352
8107 30 00	Waste and scrap	26	0.7	4	1.5
8107 90 00	Other	214	554	140	10.3

3.3 Manufacture and use of cadmium and cadmium compounds in Denmark

3.3.1 Manufacture, import, export and consumption of cadmium and cadmium compounds on its own

Cadmium and cadmium compounds are not manufactured in Denmark. A minor import and export of such goods takes place. Existing statistical data is presented in Table 9.

No recent studies of cadmium use and consumption in Denmark are available. Based on the most recent study from 2000 [Drivsholm *et al.* 2000] it is assumed that unwrought cadmium and articles of cadmium are primarily used for electroplating. Cadmium oxide may also be used for electroplating, but no evidence of this usage is available.

TABLE 9
DANISH IMPORT AND EXPORT OF CADMIUM AND CADMIUM COMPOUNDS (DS, 2012)

CN code	Text	Import, tonnes/year		Export, tonnes/year	
		Average 2006-2010	2011	Average 2006-201o	2011
2825 90 60	Cadmium oxide	0.001	0.002	0	0
28332910	Cadmium sulphates *1	0.001	0	0	0
Cadmium and articles thereof:					
8107 20 00	Unwrought cadmium; cadmium powders	0.072	0.002	0	0
8107 30 00	Cadmium waste and scrap (excl. ashes and residues containing cadmium)	0	0	0	0
8107 90 00	Articles of cadmium, n.e.s.	0.247	0.15	0.003	0.254

*1 From 2007 cadmium sulphates have not been registered separately but together with sulphates of chromium and zinc. Statistical figures from 2007 and succeeding years are therefore not presented.

3.3.2 Import, export and consumption of cadmium and cadmium compounds in preparations

Cadmium and cadmium compounds are not known to be used for manufacturing of preparations in Denmark. Some import and export of pigments based on cadmium compounds takes place. Existing statistical data is presented in Table 10. No recent studies of cadmium use and consumption in Denmark are available.

TABLE 10
DANISH IMPORT AND EXPORT OF CADMIUM AND CADMIUM COMPOUNDS (DS, 2012)

CN code	Text	Import, tonnes/year				Export, tonnes/year			
		Average 2006-2010		2011		Average 2006-201o		2011	
		Pigments	Cadmium	Pigments	Cadmium	Pigments	Cadmium	Pigments	Cadmium
32063000	Pigments etc. based on cadmium compounds *1	2.984	0.746	0	0	0	0	0	0
3206430	Pigments etc. based on cadmium compounds for colouring of all materials *1	49.605	12.401	24.540	6.135	109.07	27.267	0	0

*1 [Drivsholm *et al.* 2000] are assuming a cadmium content of 25% for similar commodities.

Data on cadmium and cadmium compounds in preparations registered in the Danish Product Register (PROBAS) are summarised in Table 11.

TABLE 11
CADMIUM AND CADMIUM COMPOUNDS IN PREPARATIONS PLACED ON THE DANISH MARKET IN 2011 AS REGISTERED IN THE DANISH PRODUCT REGISTER

Use area	Substance	Cadmium tonnes/year	Other compounds tonnes/year
Manufacturing of chemical products	Cadmium	0.001-0.01	
Manufacturing of iron and metal constructions	Cadmium	0.001-0.01	
Other uses		0.1-1.0	
Car body repair and painting	Cadmium compounds		<0.001
Other uses	Cadmium compounds		0.001-0.01

3.3.3 Import, export and consumption of cadmium and cadmium compounds in articles

No recent studies of cadmium use and consumption in Denmark are available. The consumption pattern from the most recent study from 2000 [Drivsholm et al, 2000], representing 1996 - figures is presented in Table 12. At that time batteries were by far the dominant use of cadmium in Denmark, while other uses were marginal.

TABLE 12
END USES OF CADMIUM IN DENMARK IN 1996 [DRIVSHOLM *ET AL*, 2000]

Application	Tonnes/year	%
Intended applications		
Batteries	36-54	79
Plastics and toys *1	0.2-4.1	4
Plating	0.1-0.2	<1
Alloys	0.6-0.8	1
Jewellery *2	<1.8	<2
Other intended applications *3	0.4-0.6	<1
As natural contaminant		
In zinc	0.1-2.0	2
In commercial phosphate fertilizers	1.0	2
In fossil fuels (coal, oil etc.)	1.4-2.7	4
In lime	0.8-1.7	2
In other products	2.2-2.3	4
Total	43-71	100

*1 Contains cadmium from pigments and stabilizers.

*2 Covers "cheap silver"; silver alloys for jewellery where silver is partially substituted by cadmium

*3 Includes electronic components, laboratory reagents, cosmetics and in principle solar cells, although the consumption for solar cells was estimated as zero.

Batteries remain a dominant use of cadmium in Denmark. Table 13 statistical data on import and export of separate batteries to Denmark are presented. It is strongly emphasised that these figures do not give a complete picture of the use of cadmium batteries in Denmark, as batteries are also incorporated in many types of imported electrical equipment as tools etc. However, it may be that the use of cadmium in batteries has decreased as other battery types have replaced NiCd batteries for many applications.

The latest survey on batteries from 2005 shows that consumption of NiCd batteries seemed to peak around 1997-2000, and decline through 2002 as NiCd batteries gradually were substituted by NiMH and Li-ion batteries [Maag and Hansen, 2005]. The total consumption of small portable NiCd-batteries was estimated at 185 tonnes in 2002 [Maag and Hansen, 2005], corresponding to approximately 33 tons cadmium assuming a cadmium content of 18% [Drivsholm *et al.* 2000].

In 2002 cordless power tools constituted the dominant use remaining accounting for approximately 91% of [Maag and Hansen, 2005]. Neither portable NiCd-batteries for cordless power tools nor large non-portable (not hermetically sealed) NiCd-batteries for emergency back-up systems etc. are restricted by the EU battery directive 2006/66/EC.

TABLE 13
DANISH IMPORT AND EXPORT OF SEPARATE CADMIUM BATTERIES IN 2011 (DS, 2012)

CN code	Text	Import, tonnes/year		Export, tonnes/year	
		Batteries	Cadmium	Batteries	Cadmium
85073020	Hermetically sealed nickel-cadmium accumulators (excl. spent)	39.785	7.16	30.320	5.46
85073080	Nickel-cadmium accumulators, not hermetically sealed (excl. spent)	21.041	0.63-1.58	22.692	0.68-1.70
Total			7.79-8.74		6.14-7.16

*1 For hermetically sealed batteries a cadmium content of 18% is assumed [Drivsholm *et al.* 2000]

*1 For not hermetically sealed batteries a cadmium content of 3-7.5% is assumed [Drivsholm *et al.* 2000]

Regarding other uses, the trend may be briefly assessed as follows:

The use of cadmium in plastics as pigment or stabilizer is likely at the same level or below the figures presented in Table 8, as the focus on the restrictions on the use of cadmium in theEU has only been increased with the introduction of other relevant regulation in this regard such as the EU RoHS (2011/65/EU) and ELV (2000/53/EC) Directives. In 2000 the European PVC Industry voluntary agreed in ceasing the use of cadmium stabilizers by all of its members as from 2001 [PVC Europe 2012].

The use of cadmium for plating will probably remain stable, as the use is for military purposes and therefore not covered by the existing regulation.

The use of cadmium in anodes is predominantly for sacrificial anodes used for corrosion protection of ships and iron constructions. This use is not covered by the existing REACH regulation and the consumption will likely remain stable.

The use of cadmium for jewellery was restricted in 2011 by the REACH regulation and the consumption will likely decrease.

Regarding solar cells the consumption of cadmium for this purpose in Denmark should to the best of knowledge still be considered not significant. At the EU level in 2006 the CdTe cells accounted for a few percentage of the total solar cell market as mentioned above.

Regarding the unintended use as a natural contaminant, it is noted that the consumption of commercial phosphate fertilizers in 2009-2011 has decreased significantly (to about 50%) compared with the figures in Table 8 which were based on consumption in 1994-1998 (reference is made to Section 7.2.1 and Table 21).

3.3.4 Historical development

Based on DEPA [1980], DEPA [1994], and Drivsholm *et al.* [2000] the historical development of cadmium consumption in Denmark can be briefly summarized as follows:

Around 1980, before cadmium regulation was introduced in Denmark, the total consumption of cadmium came to approximately 110 t/y, of which 60 t/y were used for pigments and stabilizers (predominantly in plastics) while 16 t/y and 6 t/y were used for plating and alloys respectively. Batteries were marketed but accounted for5 t/y only. The remaining consumption was mainly due to the presence of cadmium as a natural contaminant in zinc, coal and phosphate fertilizers.

The Danish ban on cadmium from 1983 [DME 1983], which mainly was focused on pigments, stabilizers and plating, caused a development away from the use of cadmium for these applications. The development was probably strongly assisted by a growing demand for cadmium for batteries in Denmark and internationally.

By 1990 the total consumption of cadmium in Denmark was estimated at 49 t/y, of which pigments and stabilizers accounted for 6.7 t/y (mainly pigments), while plating and alloys in total came to 0.8 t/y. The dominant use at this point was batteries accounting for about 32 t/y, while natural contaminants were reduced to a total of 10 t/y.

During the 1990'ties the picture of consumption remained largely stable. As stated in Table 12 above, the consumption for batteries has continued to grow, but had probably peaked in 1997-2000. At the EU level batteries accounted for 89% of the total cadmium consumption in 2007/2008. Whether this was also the case in Denmark is not known.

New applications of cadmium marketed included "Cheap silver" and photovoltaic cells.

The use for "cheap silver" may reflect a low world market price for cadmium. While the countries of origin for these products about year 2000 were mainly India and Nepal [Drivsholm et al 2000], the picture presented by a new study in 2008 was somewhat different. The origin of jewellery with a high content of cadmium were mainly China and "the East", accompanied by a few samples from Holland and England, while neither India, Thailand nor South Korea were important in this context [Strandesen & Poulsen, 2008].

Photovoltaic cells based on cadmium-telluride and similar compounds could develop into a new significant market for cadmium. Regarding the trend after 2000 reference is made to section 3.3.3 above.

3.3.5 Summary on the use of cadmium and cadmium compounds in Denmark

No recent studies on the use of cadmium in Denmark are available. The most recent study indicates batteries as being the dominant application of cadmium in Denmark. Consumption for other intended applications including pigments, stabilizers, alloys, plating, electronic components, laboratory reagents, cosmetics and solar cells, is small.

It is important to recognize that cadmium is a by-product of zinc mining, and production of cadmium internationally is more dependent on zinc refining volumes than on market demand. Therefore restrictions on cadmium for some applications are likely to promote development of new applications of cadmium.

At present, consumption internationally seems stable with batteries as the all-dominating field of application. Photovoltaic cells are seen as an application that could develop into a new significant market for cadmium.

4. Waste management

4.1 Waste from manufacture and use of cadmium and cadmium compounds

Manufacture of cadmium will always generate waste containing cadmium. Disposal of this waste depends on the form of cadmium (metal or compound) present in the waste and the actual concentration in the waste. Waste exceeding certain thresholds is treated as hazardous waste. The lowest threshold for being characterized as hazardous waste is related to cadmium oxide [DME 2011]. In this case a threshold of 0.1% of the waste weight is prescribed. For other compounds and cadmium metal the threshold may be higher.

At the EU level, industrial sources were estimated to account for about 60% of the total sources of cadmium to landfills in year 2000. Around half of this contribution is associated with the intentional use of cadmium e.g. cadmium processing, iron and steel processing (cadmium in scrap) and a small part of the non-ferrous metals processing (cadmium alloys). It is estimated that residues from cadmium processing counts for approximately 400 t/y of cadmium and approximately 16% of the supply of cadmium to landfills in the EU [Hansen *et al.* 2002].

4.2 Waste products from the use of cadmium and cadmium compounds in mixtures and articles

Most companies using cadmium in manufacturing processes are assumed to have systems for internal recycling in place. For cadmium being incorporated into articles some recycling takes place while other articles are disposed of as waste at the end of their service life. Articles for which significant recycling takes place include batteries, alloys, and plastics.

Regarding recycling of batteries, it is estimated that approximately 86% of cadmium available for collection with industrial batteries and approximately 47% of cadmium available for collection with portable batteries is actually collected for recycling (2002-figures), while the remainder is disposed of either as municipal waste or as industrial waste for special landfilling [EC 2007].

Regarding alloys the metal value of many alloys in itself guaranties effective collection, although no figures are available to illustrate the collection rate. In most cases the alloys including cadmium are recycled by being mixed with other scrap metal and turned into new alloys.

Recycling of PVC in the EU has exceeded 260.000 tons/year in 2010 [Vinyl 2010, 2012]. PVC is recycled together with its content of cadmium thus integrating cadmium into new PVC-products. An interesting consequence of this development is that it has required considerations on the EU level as to, whether the existing threshold for cadmium in PVC should be raised from the present 100 ppm to 1000 ppm [RPA 2010].

Other examples of plastic recycling includes recycling of bottle crates for beer and softwater bottles. In Denmark such crates are in reality being operated in a closed cycle, where damaged crates are remelted into new crates with very little loss [Drivsholm *et al.* 2000].

Generally for all articles not being recycled, these articles will end up in municipal waste. It is estimated that in 1996 about 12 - 24 t/y of cadmium was directed to landfills and other depots in Den-

mark inclusive of civil works such as roads etc. used for disposal of incineration clinkers and other residual waste products [Drivsholm *et al. 2*000].

4.3 Releases of cadmium and cadmium compounds from waste disposal

Cadmium is an element and cannot be destroyed by waste treatment.

Cadmium in articles disposed of as municipal waste will generally be directed to incineration or landfilling.

By incineration the majority of cadmium will be collected as flue gas cleaning residues, while a significant amount will be present in clinker and small amounts of cadmium will be released to air and waste water.

Data from two incineration plants in Austria and Denmark, respectively, indicates the relative importance of the outlets as follows: emitted to air: 0.2-1 %; emitted to waste water: <1%; collected with flue gas cleaning residues: 90-94 %; collected with clinker: 6-9% [Hansen *et al. 2*002].

For comparative purposes, the latest Substance Flow Analysis for cadmium in Denmark estimated the following total outlet from municipal waste incineration in Denmark [Drivsholm *et al. 2*000]:

Emitted to air: 0,2- 0,4 tons/year (2%)
Collected with flue gas cleaning residues: 8-17 tons/year (90%)
Collected with clinker: 0,7-1,4 tons/year (8%)

In Denmark flue gas cleaning residues are landfilled, while clinker is often used for civil works such as road construction etc.

According to Eurostat [2012] in 20120 about 48% of all waste in the EU is landfilled. According to Hansen *et al* [2002] landfills in the EU range from unlicensed simple dumpsites without any leachate control to highly controlled landfills for hazardous waste. Not all licensed landfills are equipped with membranes and leachate collection.

The fate of heavy metals in landfills is described in [Hansen *et al. 2*002], from which an extract is presented below". In this context the term "heavy metals" is representative for cadmium:

"Heavy metals in leachate from landfills have been extensively studied and monitored. Compared to the total amount of heavy metals disposed into landfills the content of heavy metals in leachate is relatively low. The major part of the metals is retained in the landfill. As a consequence, it must be expected that leaching of heavy metals from the landfills will continue for a long time.

During the active life of a sanitary landfill, the leachate created will typically be collected and undergo some kind of wastewater treatment. For financial reasons the leachate is often treated together with municipal sewage. By this sort of treatment, a significant amount of the heavy metals present in leachate will be retained in sewage sludge, while the rest will be emitted to the water environment. The amount retained in sludge will be directed to farmland, incineration or deposited again on landfills. A cycle is therefore created that in time will allow all heavy metals in leachate to be emitted to the environment. The active life of the landfill includes the period, when waste is sent to the landfill as well as the time that follows, when no more waste is dumped and the final top cover has been established, but leachate is still collected for treatment.

Model calculations on the time needed before leachate from different landfills can be released to groundwater without risk shows that up to several hundred years may be needed depending on the amount of metal present and the amount of leachate created.

The degradation process in landfills over times lead to different stages of ageing with leachate composition quite different from the young landfill. Often, there will be great variability within the landfill body itself, resulting in different degradation phases in various parts of the landfill.

During the stage of anoxic conditions and methane production which will be reached after a short time (months), the mobility of the heavy metals is in general low due to formation of relatively insoluble compounds. During the later oxidised state where the degradation of the organic material lead to formation of carbon dioxide, the mobility of the heavy metal will increase leading to higher content of heavy metals in the leachate.

The concentration of soluble metals will not only depend on the actual chemical conditions and speciation of the metals, but also the degradation or disintegration of products in which the metals are embedded. A significant part of the heavy metals in the waste will be bound in glass, plastics, slag, ceramics, steel, wood etc. Products and materials stored in a landfill should be expected to slowly disintegrate over time. Plastics will probably degrade in time due to biological and chemical processes including weathering processes (Hansen *et al* [2004] argues with reference to amber that the degradation time in landfills may actually be very long). *Glass is known to disintegrate over time in a humid environment. Slag from incineration plants should be expected to disintegrate into a clay-like material. Metals should be expected slowly to be oxidized and thereby be dissolved. Wood and organic materials will decompose due to biological and chemical processes. Many of these processes are slow and strongly influenced by the presence of oxygen, water and acids.*

Transport of heavy metals within a mature landfill can be compared to transport in soil and should thus generally be taken as a very slow process. The exact rate of transport will, however, vary with the metal in question, the composition of materials and the chemical conditions within the landfill. The time required for a complete wash-out of a specific metal may be in the range of hundreds to thousands of years or even more. For all metals, the major part cannot be expected to be washed out before long time after any leachate collection has been discontinued.

The studies of landfill ageing mainly cover what in the long time perspective must be considered the initial phases - the phases of relevance for understanding the methane production dynamics and leachate composition. Taking a closer look at older disused landfills a number of uncontrolled processes takes place. Landfills will after some time often be covered by trees with roots deep down in the former landfill and construction works may mix up the upper parts. Large parts of cities today are build on old waste dumps. The landfill will after some time become a part of the environment - a highly contaminated part of the environment. If the information systems in the future work as they do today, the information on former landfill sites may remain for the necessary hundreds to thousands of years, but actually nobody knows. Probably these highly contaminated parts of the environment will remain and slowly be absorbed into the surroundings until major geological events occur. In the northern part of Europe this may ultimately happen when a new Ice Age leads to that the remains of landfills are eroded away by the ice and their content of e.g. heavy metals spread over large areas."

5. Environmental effects and fate

5.1 Classification

As can be seen from the overview of existing legislation (Chapter 2) a range of cadmium compounds are subject to harmonised classification and labelling. Most of these compounds are classified for acute and chronic hazards to the aquatic environment in Category 1. Less soluble compounds appear much less toxic, as illustrated by cadmium sulphide which is classified for chronic hazards to the aquatic environment in Category 4. Illustrative examples are reproduced in Table 14 with associated explanations of the classification abbreviations. This same classification pattern is seen in the Self-Classifications in the C&L inventory (Appendix 2).

TABLE 14
EXAMPLES OF HARMONISED CLASSIFICATIONS - ENVIRONMENT

Index No	International Chemical Identification	CAS No	Classification	
			Hazard Class and Category Code(s) *1	Hazard statement Code(s) *1
048-002-00-0	Cadmium (non-pyrophoric)	7440-43-9	Aquatic Acute 1 Aquatic Chronic 1	H400 H410
048-002-00-0	cadmium oxide (non-pyrophoric)	1306-19-0	Aquatic Acute 1 Aquatic Chronic 1	H400 H410
048-010-00-4	Cadmium sulphide	1306-23-6	Aquatic Chronic 4	H413

*1 Aquatic acute toxicity Category 1/H400: Very toxic to aquatic life
Aquatic chronic toxicity Category 1/H 410: Very toxic to aquatic life with long lasting effects
Aquatic chronic toxicity Category 4/ H413: May cause long lasting harmful effects to aquatic life

5.2 Environmental transport and effects

UNEP [2010] has published a review of scientific information on cadmium. An extract of this summary is presented below:

"In the environment, cadmium is toxic to plants, animals and micro-organisms. Being an element, cadmium is persistent – it cannot be broken down into less toxic substances in the environment. The degree of bioavailability and potential for effects varies depending on the form of cadmium. Cadmium bioaccumulates mainly in the kidneys and liver of vertebrates and in aquatic invertebrates and algae.

Environmental transport: extent to which cadmium is transported on intercontinental, regional, national and local scales

Cadmium is released by various natural and anthropogenic sources to the atmosphere, aquatic environments (fresh and salt water environments) and terrestrial environments. There are fluxes between these compartments. Cadmium released to the atmosphere can deposit to land and

aquatic environments, and some cadmium released to soil over time will be washed out to the aquatic environments. The long-term sinks are deep-sea sediments and, to a certain extent, controlled landfills, in cases where, owing to its physico-chemical properties, cadmium is immobilized and remains undisturbed by anthropogenic or natural activity (climatic and geological).

Cadmium, once emitted to air, is subject to atmospheric transport. It is mainly emitted to the atmosphere in particle form. The atmospheric transport of cadmium is governed by aerosol (particle) transport mechanisms: in the atmosphere, cadmium may be transported on local, national, regional or intercontinental scales, depending on various factors, including, for both natural and anthropogenic sources, particle size, the height of emission outlets and meteorology. Because it has a relatively short residence time in the atmosphere (days or weeks), however, this metal is mainly transported over local, national or regional distances.

Based on the relatively scarce specific evidence available, cadmium is considered to be subject to a certain degree of long-range air transport on an intercontinental scale. Intercontinental transport is, however, expected to make only a minor contribution to cadmium levels in regions affected by other, local emitting sources. The regional and intercontinental atmospheric transport of cadmium contributes to deposition in remote regions, such as the Arctic, where there are few local sources for cadmium releases.

With regard to aquatic systems, rivers transport cadmium and other heavy metals on a national and regional scale. Ocean transport also occurs. The oceanic residence time of cadmium has been estimated at about 15,000 years. This indicates that cadmium may be accumulated and transported in significant amounts over long distances in the ocean. It should be noted, however, that oceans have large natural reservoirs of cadmium. The contribution of cadmium via rivers into the marine environment of the North Sea is in the same order of magnitude as the atmospheric deposition, which is the other main pathway of cadmium inputs in the region.

Impacts on the ecosystem

Cadmium is a non-essential heavy metal. Some cadmium compounds are relatively water soluble, mobile in soil and bioavailable, depending on the water and soil chemistries. It tends to bioaccumulate in organs such as the kidney and liver of vertebrates, but aquatic invertebrates and algae can also build up relatively high concentrations. Effects on birds and mammals are mainly due to kidney damage. In sea birds and marine mammals in particular, cadmium accumulates to relatively high levels.

In terrestrial ecosystems, soil micro-organisms and plants are more sensitive to cadmium than soil invertebrates. Both invertebrates and plants can accumulate cadmium. Predators feeding on such soil invertebrates can introduce cadmium into the food chain, which suggests a risk of secondary poisoning through the food chain from worms to higher trophic levels (birds or mammals). The accumulation of cadmium by plants results in this contaminant entering the human food chain. In some European areas, the cadmium concentrations measured and estimated are exceeding the threshold concentration for adverse effects on terrestrial ecosystems. In the United Nations Economic Commission for Europe region, available information indicates that levels of cadmium in terrestrial wildlife are generally low and do not exceed thresholds for effects.

Aquatic fresh water and marine invertebrates are the organisms most sensitive to cadmium. The dissolved cadmium concentrations measured in some European waters (mainly rivers) are exceeding the threshold concentration producing adverse effects of cadmium in the aquatic ecosystem. Some studies suggest that levels in water, sediment and soil are at or above known biological effect levels. Despite relatively high levels of cadmium in seabirds and marine mammals in Greenland, no evidence has been found of effects in ringed seals with very high cadmium levels in their kidneys. Arctic seabirds in general are known to accumulate high levels of cadmium found naturally in the marine environment and are therefore considered to be not as sensitive as terrestrial

birds. Kidney damage has, however, been reported in wild colonies of Arctic pelagic seabirds having cadmium levels of 60-480 µg/g in the kidney. Spatial distribution of cadmium in marine biota appears to be driven by regional geology or geochemistry. Monitoring data on cadmium in the Arctic abiotic and biotic environment to date, however, provide no conclusive evidence of trends or effects."

5.3 EU Water Framework Directive

The EU Water Framework Directive (2008/105/EC) has established quality standards for surface waters. The consequence of these standards in Denmark was assessed by Kjølholt *et al.* [2007].

The concentration of cadmium in discharges from Danish sewage treatment plants has been determined at an average of 0.09 µg Cd/L and a 95%-fractile of 0.5 µg Cd/L, which can be compared to a quality standard of 0.08 µg Cd/L as annual average and a lowest maximum allowable concentration of 0.45 µg Cd/L . The concentration of cadmium in separate discharges for rain water is determined at 0.73 µg Cd/L, exceeding the lowest maximum allowable concentration of 0.45 µg Cd/L .

In a large Danish stream concentrations of 3.4 µg Cd/L have been measured, while the average median concentration in Danish streams is calculated at 0.046 µg/L (Table 18).

It was concluded by Kjølholt *et al.* [2007] that it will be necessary to achieve further reduction of cadmium emissions to Danish surface waters in order to comply with the Water Framework Directive.

6. Human health effects

6.1 Classification

As can be seen from the overview of existing legislation (Chapter 2) a range of cadmium compounds are subject to harmonised classification and labelling. Most of these compounds are classified for carcinogenicity, mutagenicity and as toxic for reproduction (CMR), as well as for acute toxicity following inhalation and for having the capacity to damage organs after repeated exposure.

This common classification is also found in the Self-Classifications in the C&L inventory (Appendix 2). For illustrative purposes the harmonised classifications for cadmium and cadmium oxide are reproduced in Table 15 followed by an explanation of classification abbreviations.

TABLE 15
EXAMPLES OF HARMONISED CLASSIFICATIONS - HUMAN HEALTH

Index No	International Chemical Identification	CAS No	Classification	
			Hazard Class and Category Code(s) *1	Hazard state-ment Code(s) *1
048-002-00-0	Cadmium (non-pyrophoric)	7440-43-9	Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 STOT RE 1	H350 H341 H361fd H330 H372
048-002-00-0	cadmium oxide (non-pyrophoric)	1306-19-0	Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 STOT RE 1	H350 H341 H361fd H330 H372

*1 Carcinogenicity Category 1B/H350: May cause cancer
Mutagenicity Category 2/H341: Suspected of causing genetic defects
Reproductive toxicity category 2/H361fd: Suspected of damaging fertility. Suspected of damaging the unborn child
Acute toxicity category 2/ H330: Fatal if inhaled
Specific target organ toxicity (STOT) cat. 1/H372: Causes damage to organs through prolonged or repeated exposure.

6.2 Human health effects

WHO [2010] has published a summary assessment for cadmium based on existing WHO assessment documents including UNEPs "*Draft final review of scientific information on cadmium*" [UNEP 2008]. An extract of this summary is presented below. It is supplemented by an extract of the summary from UNEPs *Final review of scientific information on cadmium - version of December 2010* [UNEP 2010]:

"Cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen. It is generally present in the environment at low levels; however, human activity has greatly increased those levels.

Cadmium can travel long distances from the source of emission by atmospheric transport. It is readily accumulated in many organisms, notably molluscs and crustaceans. Lower concentrations are found in vegetables, cereals and starchy roots. Human exposure occurs mainly from consumption of contaminated food, active and passive inhalation of tobacco smoke and inhalation by workers in the non-ferrous metal industry. National, regional and global actions are needed to decrease global environmental cadmium releases and reduce occupational and environmental exposure.

Sources of exposure to cadmium

Cadmium can be released to the environment in a number of ways, including: natural activities, such as volcanic activity (both on land and in the deep sea), weathering and erosion, and river transport; human activities, such as tobacco smoking, mining, smelting and refining of non-ferrous metals, fossil fuel combustion, incineration of municipal waste (especially cadmium-containing batteries and plastics), manufacture of phosphate fertilizers, and recycling of cadmium-plated steel scrap and electric and electronic waste; remobilization of historic sources, such as the contamination of watercourses by drainage water from metal mines.

Cadmium releases can be carried to and deposited on areas remote from the sources of emission by means of long-range atmospheric transport.

Industrial processes

The majority of cadmium present in the atmosphere is the result of human activities, especially smelting of non-ferrous metal ores, fossil fuel combustion and municipal waste incineration. Soluble inorganic cadmium compounds are of greatest concern for occupational safety. Occupational exposure of workers in the non-ferrous smelting industry can be significant. Smelting and mining operations contaminate the aquatic environment, as does the effluent produced by air pollution control (gas scrubbers, in the absence of strict control measures). Atmospheric deposition of cadmium on arable soils exceeds its elimination in many countries, resulting in a gradual increase in cadmium levels in soils and crops. Application of municipal sewage sludge to agricultural soil can also be a significant source of cadmium.

Food and drinking-water

Cadmium contained in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food-chain. Food constitutes the main environmental source of cadmium for non-smokers. Highest cadmium levels are found in the kidney and liver of mammals fed with cadmium-rich diets and in certain species of oysters, scallops, mussels and crustaceans. Lower cadmium concentrations are found in vegetables, cereals and starchy roots. Owing to the larger consumption of such food items, they represent the greater part of daily cadmium intake in most populations. Some crops, such as rice, can accumulate high concentrations of cadmium if grown on cadmium-polluted soil. Acidification of cadmium-containing soils may increase the cadmium concentrations in crops.

Cadmium exposure from drinking-water is relatively unimportant compared with exposure from the diet. However, impurities in the zinc of galvanized pipes and solders in fittings, water heaters, water coolers and taps can sometimes lead to increased cadmium levels in drinking-water.

Smoking

The tobacco plant naturally accumulates relatively high concentrations of cadmium in its leaves. Thus, smoking tobacco is an important source of exposure, and the daily intake may exceed that

from food in the case of heavy smokers. Cigarette smoking can cause significant increases in the concentrations of cadmium in the kidney, the main target organ for cadmium toxicity.

TABLE 16
WORLD HEALTH ORGANIZATION (WHO) CADMIUM GUIDELINES

Provisional tolerable monthly intake (PTMI)	
The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) recently (in 2010) established a provisional tolerable monthly intake for cadmium of 25 µg/kg body weight.	
Drinking-water	*3 µg/L*
Air	***5 ng/m^3 (annual average)***

Health effects
The kidney is the critical target organ. Cadmium accumulates primarily in the kidneys, and its biological half-life in humans is 10–35 years. This accumulation may lead to renal tubular dysfunction, which results in increased excretion of low molecular weight proteins in the urine. This is generally irreversible.

High intake of cadmium can lead to disturbances in calcium metabolism and the formation of kidney stones. Softening of the bones and osteoporosis may occur in those exposed through living or working in cadmium-contaminated areas. In an area of Japan where soil has been contaminated with cadmium from zinc/Lead mines, Itai-itai disease used to be widespread and is still seen in women over 50 years of age. It is characterized by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction.

High inhalation exposure to cadmium oxide fume results in acute pneumonitis with pulmonary oedema, which may be lethal. Long-term, high-level occupational exposure is associated with lung changes, primarily characterized by chronic obstructive airway disease.

There is sufficient evidence that long-term occupational exposure to cadmium (e.g. through cadmium fume) contributes to the development of lung cancer. There is limited evidence that cadmium may also cause cancers of the kidney and prostate. The International Agency for Research on Cancer (IARC) has classified cadmium and cadmium compounds as ***carcinogenic to humans*** *(Group 1), meaning that there is sufficient evidence for their carcinogenicity in humans."*

Extract of the summary from UNEPs *Final review of scientific information on cadmium - version of December 2010* [UNEP 2010]:

"Cadmium is a non-essential and toxic element for humans. Attention is drawn to the following:

- *The kidney is considered the critical target organ for toxicity of cadmium in humans. The main critical effects include an increased excretion of proteins in urine as a result of proximal tubular cell damage. The severity of the effect depends on duration and magnitude of exposure*
- *Skeletal damage is another critical effect of chronic cadmium exposure at levels somewhat higher than those for which kidney proteinuria is an early effects indicator*
- *Cadmium is a human carcinogen by the inhalation route. Epidemiological data from occupational settings confirm lungs being the primary target organ. Cadmium is not considered a carcinogen by ingestion*

- *Cadmium is mainly stored in the liver and kidneys. Excretion is slow, with a very long half-life (decades) in the human body. Cadmium concentrations in most tissues increase with age*
- *There are multiple sources of cadmium exposure in the general population. Attention is drawn to the following:*
- *Food accounts for approximately 90 per cent in the general, non-smoking population*
- *Cadmium in crops is due to the uptake of cadmium from soils and the rate of uptake is influenced by factors such as soil pH, salinity, humus content, crop species and varieties and the presence of other elements (e.g., zinc)*
- *Less than 10 per cent of the total exposures among general populations occur due to inhalation of low levels of cadmium in ambient air and through drinking water*
- *The kidney burden resulting from cumulative exposure to cadmium can be assessed by measuring cadmium in urine*

Some population groups are especially vulnerable to increased exposure and uptake of cadmium. Attention is drawn to the following:

- *Cadmium occurs in all food, but agricultural crops (particularly irrigated rice) generally account for most of the intake. Vegetarians and high cereal-consuming and pulse-consuming groups are likely to have higher exposures compared to the general population*
- *People with a high intake of shellfish and organ meat from marine animals may have a particularly high intake of cadmium*
- *People with low body iron stores, especially pregnant women, or low zinc intake will exhibit higher rates of cadmium uptake*
- *People with other nutritional deficiencies may also be at risk*
- *Tobacco is an important source of cadmium uptake in smokers and may also affect non-smokers through passive exposure to secondary smoke*
- *People living in the vicinity of industrial sources and other point sources of cadmium release can be exposed to an increased level of cadmium.*
- *Certain population groups are vulnerable and especially susceptible to cadmium. Attention is drawn to the following:*
- *People who have medical detriments from a range of other clinical conditions, particularly those related to renal insufficiency (e.g. diabetes) and multiparous women with inadequate nutrition, are more susceptible*
- *Renal efficiency normally decreases with age and can be exacerbated by exposure to cadmium*

The level of dietary exposure can exceed the guidelines set by the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Attention is drawn to the following:

- *According to available data, the average weekly intake of cadmium from food in most countries is within the range of 0.7–2.8 µg/kg body weight*
- *Although available data indicate that most people have intake levels below the provisional tolerable weekly intake (PTWI) (7 µg/kg body weight per week), WHO recognizes that the margin between the PTWI and the actual weekly intake of cadmium by the general population is small, less than 10-fold, and that this margin may be even smaller in smokers*
- *In some populations at high risk, the margin may be non-existent"*

It should be noted that while the Joint FAO/WHO Expert Committee on Food Additives has established a provisional tolerable monthly intake of 25 µg/kg bw (Table16 above), the European Food Safety Committee (EFSA) in 2009 based on analysis of new data set a reduced tolerable weekly intake for cadmium of 2.5 µg/kg bw to ensure sufficient protection of all consumers [EFSA 2009].

7. Monitoring data and exposure

7.1 Monitoring of cadmium and cadmium compounds in the environment and releases from point sources in Denmark

Cadmium is included in the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment, NOVANA. As shown in Table 17 this monitoring programme covers point sources as well as streams, deposition from air and inorganic tracers.

TABLE 17
CADMIUM AND CADMIUM COMPOUNDS INCLUDED IN THE NATIONAL MONITORING AND ASSESSMENT PROGRAMME FOR THE AQUATIC AND TERRESTRIAL ENVIRONMENT, NOVANA 2011-2015

Substance	Point sources	Streams	Air	Inorganic tracer
Cadmium	X	X	X	X

TABLE 18
MOST RECENT MONITORING DATA FOR CADMIUM IN THE ENVIRONMENT FROM THE NATIONAL NOVANA

Medium	Number of samples *1	Median (maximum) concentration	Unit	Year	Source
Air (background - Anholt)	Yearly averaging	0.22	µg/m³	2010	Ellermann *et. al.* 2010
Air deposition (background - land)	*2	39	µg/m²	2010	Ellermann *et. al.* 2010
Air deposition (background - water)	*2	26	µg/m²	2010	Ellermann *et. al.* 2010
Inorganic tracers	5	0.22 (0.7)	µg/L	1998-2003	Grant *et al.* 2005
Lakes (water)	96	0.019-0.002 (0.14)	µg/L	1999/2001	Boutrup *et al.* 2006
Lakes (sediment)	25	0.69 (5.94)	mg/kg DW	2008	Bjerring *et al.* 2010
Streams (water)		n.d.-3.4	µg/L	2001	Boutrup *et al.* 2006
Streams (sediment)	21 (21)	0.72 (3.05)	mg/kg DW	2009	Wiber-Larsen *et al.* 2010

Medium	Number of samples *1	Median (maximum) concentration	Unit	Year	Source
Marine waters (mussels)		0.5-1.2	mg/kg DW	2003	Boutrup *et al.* 2006
Ground water	933	0.008 (9.7)	µg/L	1998-2003	Jørgensen 2004

*1 Number of positive samples in bracket

*2 Yearly deposition estimated based on measurements of bulk wet deposition on 6 measurements stations in Denmark and dry deposition assessed based on measurements of air concentrations on the island of Anholt.

*3 Measurements cover 5 large Danish streams. Median concentration varier from not detected to 3.4 µg/L. The average median concentration is calculated at 0.046 µg/L.

TABLE 19
OTHER RELEVANT MONITORING DATA FOR CADMIUM IN THE DANISH ENVIRONMENT

Medium	Number of samples	Median (maximum) concentration	Unit	Year	Source
Soil - all	393	0.16 (0.04-0.45)*1	mg/kg	1992-93	Jensen *et al.* 1996
Soil - agricultural	311	0,18	mg/kg	1992-93	Jensen *et al.* 1996
Soil -sandy	226	0.13	mg/kg	1992-93	Jensen *et al.* 1996
Soil - clayish	167	0.22	mg/kg	1992-93	Jensen *et al.* 1996

*1 Figures in brackets represents 5% -fractile and 95%-fractile respectively.

Based on the air deposition rate to land of 39 µg Cd/m^2 stated in Table 18, the air deposition on the Danish land surface area can be estimated at approximately 1.7 t/y in 2010. This approximation can be compared to an estimated deposition of 3.9 t/y in 1996 [Drivsholm *et al.* 2000] and 12.6 t/y in 1980 [DEPA 1980].

7.2 Emissions to the environment in Denmark

No recent studies of cadmium emissions to the environment in Denmark are available. The emission pattern disclosed by the most recent study from 2000 [Drivsholm et al, 2000], dealing with 1996-figures is presented in Table 20. At that time waste incineration and combustion of oil products were the main sources for emission to air. Waste water, rain water and sacrificial anodes were the dominant sources for emission to water, while use of fertilizer, agricultural lime and corrosion of galvanized products dominated contributions to the soil environment.

TABLE 20
EMISSION OF CADMIUM TO ENVIRONMENT IN DENMARK IN 1996 [DRIVSHOLM ET AL, 2000]

Process/source	Estimated emission to (tons Cd/year)		
	Air	Water	Soil
Cement manufacturing	0-0.03		
Coal combustion	0.04		
Combustion of oil products	0.003-1.1		0-0.2
Use of sacrificial anodes		0.6	

Process/source	Estimated emission to (tons Cd/year)		
	Air	Water	Soil
Galvanised products			0.1-0.5
Use of fertilizer (inclusive of manure)			1.2
Use of agricultural lime			0.6-1.2
Steel manufacturing	0.02		
Solid waste incineration	0.2-0.4		
Biological waste treatment			0.1-0.2
From landfills and depots		0-0.0017	
Hazardous waste treatment	0.005	0-0.001	
Waste water and rain water		0.3-1.4	0.01
Sewage sludge	0-0.02		0.16
Total	0.3-1.6	0.9-2	2.2-3.5

7.2.1 Supply of cadmium to Danish farmland with commercial phosphate fertilizer, 1984-2002

Cadmium is a natural contaminant in the raw phosphate used for manufacturing of commercial phosphate fertilizers. In order to limit the supply of cadmium to Danish farmland and thereby ultimately limit the exposure of the Danish population to cadmium from agricultural products produced by Danish farmers, a threshold for cadmium in commercial phosphate fertilizers was introduced in 1989 (BEK. nr. 223 af 05/04/1989).

The threshold is 110 mg cadmium (Cd) per kg phosphate (P) and applies to commercial fertilizers based on raw phosphate with a total content of phosphate of 1% and above.

TABLE 21
SUPPLY OF PHOSPHATE AND CADMIUM TO DANISH FARMLAND WITH COMMERCIAL FERTILIZERS 1984-2011 [PLANTEDIREKTORATET 2004; NATURERHVERVSSTYRELSEN 2012A; NATURERHVERVSSTYRELSEN 2012B]

Year	Phosphate (P) Tonnes	Cadmium (Cd) kg	Cd/P mg/kg
1984	n.c.	3,998	n.c.
1985	n.c.	6,092	n.c.
1986	42,921	3,324	77.4
1987	44,850	4,263	105.7
1988	42,778	3,801	88.9
1989	39,629	3,767	95.0
1990	38,296	2,609	68.1
1991	44,558	3,302	74.2
1992	31.299	2,414	77.3
1993	27,761	1,408	50.7

Year	Phosphate (P) Tonnes	Cadmium (Cd) kg	Cd/P mg/kg
1994	23,324	1,482	63.6
1995	26,807	1,831	68.3
1996	23,335	1,046	44.8
1997	24,829	1,037	41.7
1998	n.c.	n.c.	n.c.
2000	19,485	223	11.4
2001	18,040	334	18.5
2002	15,572	203	13.1
2002/03	14,100	n.c.	n.c.
2003/04	15,000	n.c.	n.c.
2004/05	15,100	n.c.	n.c.
2005/06	13,500	n.c.	n.c.
2006/07	13,900	n.c.	n.c.
2007/08	13,800	n.c.	n.c.
2008/09	7,200	n.c.	n.c.
2009/10	11,000	n.c.	n.c.
2010/11	11,300	n.c.	n.c.

n.c.: not calculated

In order to monitor the content of cadmium in commercial phosphate fertilizers, about 150 samples of phosphate fertilizers are analyzed yearly for cadmium. The Danish EPA is informed in case the individual samples exceed the threshold established.

The knowledge available regarding supply of phosphate and cadmium to Danish farmland is presented in Table 21. As shown, the supply of cadmium has been strongly reduced which is a consequence of reduced consumption of phosphate fertilizers as well as reduced content of cadmium in fertilizers.

Thresholds for the content of cadmium in commercial phosphate fertilizers are currently under consideration by the European Commission ([EC2003]). According to Knudsen [2012] a threshold of 138 mg Cd/kg P for fertilizers containing more than 2.2% P is the most recent proposal for such as threshold.

7.3 Human exposure and biomonitoring

7.3.1 Cadmium – dietary exposure in the Danish population

Surveys of cadmium in food products available on the market in Denmark and estimation of dietary exposure of the Danish population are carried out at some intervals by the Danish Veterinary and Food Administration under the Ministry of Food, Agriculture and Fisheries. Based on the most recent Danish data available covering the period of 2004-2010 DTU Food [2012] has prepared an

assessment of the dietary exposure in the Danish population. An extract of this assessment is presented below. Attention must be paid to that the European Food Safety Committee (EFSA) in 2009 set a reduced tolerable weekly intake for cadmium of 2.5 µg/kg body weight [EFSA 2009](reference is made to chapter 6):

"***Methodology***
The dietary exposure was calculated by combining information on the cadmium content in foodstuffs and information on the consumption of the individual foodstuffs.

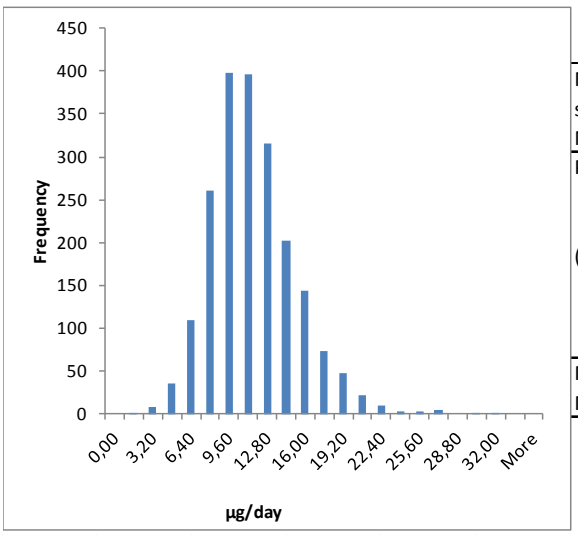
For the occurrence data, the mean values in the foodstuffs were used in order to reflect the consumer's long-term exposure to cadmium in the marketed foodstuffs. As a first choice data obtained from national control/surveillance projects on cadmium in foodstuffs in the period 2004-2010 was used. For food items not included in the analytical surveys, concentration data from similar foodstuffs were transferred. For foodstuffs, where no data were available, data from the previous report from 2003 was used (reference is made to [Danish Food Administration, 2003]).

For analytical results below the limit of detection, the mean value was used as the best approximation to the real content, rather than using zero or the limit of detection value, which would lead to an under- or overestimation, respectively. Food consumption data were obtained from the Danish food consumption survey.

Estimation of cadmium exposure
Figure 1 illustrates the distribution in cadmium intake by the Danish population in µg/day. The mean intake at 10.8 µg/day is similar to the previously reported intake of Danish adults at 10 µg/day for the time period 1998-2003.

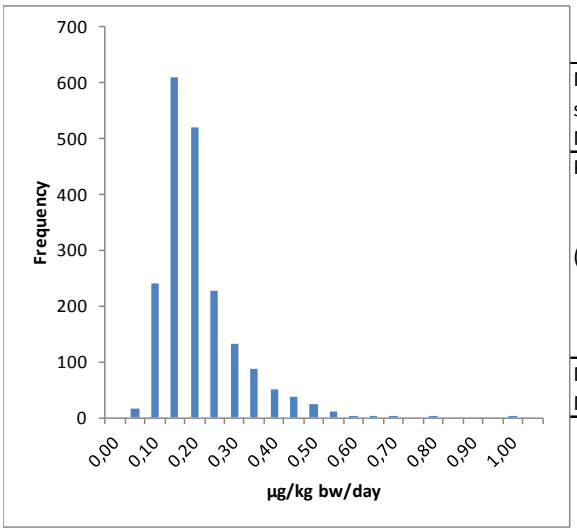
Figure 2 illustrates the distribution in cadmium intake in µg/kg bw/day by the Danish population when taking the individual body weights of the respondents into account. The intake may then be directly compared with the TWI (EFSA:Tolerable Weekly Intake) value at 2.5 µg/kg bw/week (=0.36 µg/kg bw/day). The mean intake at 0.18 µg/kg bw/day corresponds to 50% of the TWI value. The data shows that between 5-10% of the Danish population has an intake, which exceeds the TWI value.

FIGURE 1 DISTRIBUTION OF CADMIUM INTAKE IN µG/DAY BY THE DANISH POPULATION (4-75 YEARS)



		µg/day
Mean		10,8
sd		3,6
N		2033
Percentiles	1	4,0
	5	5,8
	25	8,4
(median)	50	10,4
	75	12,8
	95	17,2
	99	20,8
Minimum		1,4
Maximum		30,7

FIGURE 2
DISTRIBUTION OF CADMIUM INTAKE IN µG/KG BW/DAY BY THE DANISH POPULATION BOTH CHILDREN AND ADULTS (4-75 YEARS)



		µg/kg bw/day
Mean		0,18
sd		0,10
N		1974
Percentiles	1	0,05
	5	0,08
	25	0,12
(median)	50	0,16
	75	0,22
	95	0,38
	99	0,52
Minimum		0,02
Maximum		0,97

The majority in the group exceeding the TWI value are children, who have a relative high intake per kg bodyweight, mainly due to their lower bodyweight compared to adults.

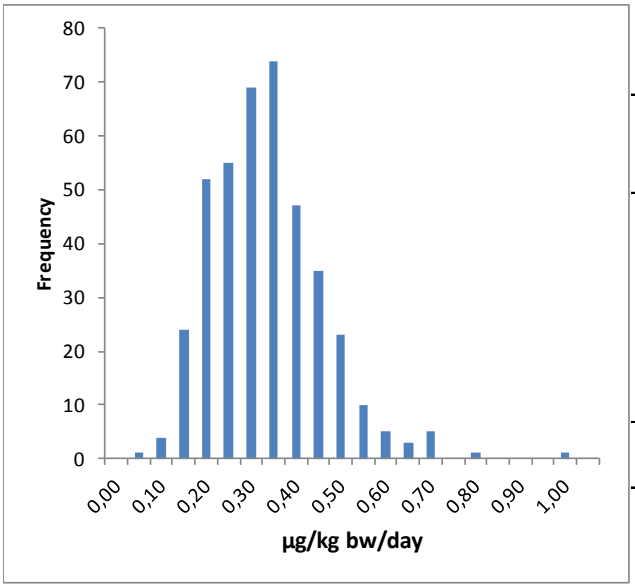
Figure 3 shows the distribution in the groups of children (4-14 years). For the children (4-14 years) the mean intake is 31 µg/kg bw/day (86% of TWI) and approximately one fourth of this group exceed the TWI value.

It should be noted that for children, the risk of adverse effects is considered to be low, since the effects used to establish the health-based guidance value are not observed until around 50 years of exposure.

When only looking at adults (15-75 years) (figure 4) the mean exposure is 0.15 µg/kgbw/day (42% of TWI) and less than 1% exceed the TWI value. This is lower than the estimated cadmium exposure in Danish adults reported by EFSA in 2009 at 2.26 µg/kg bw/day (=0.32 µg/kg bw/day).

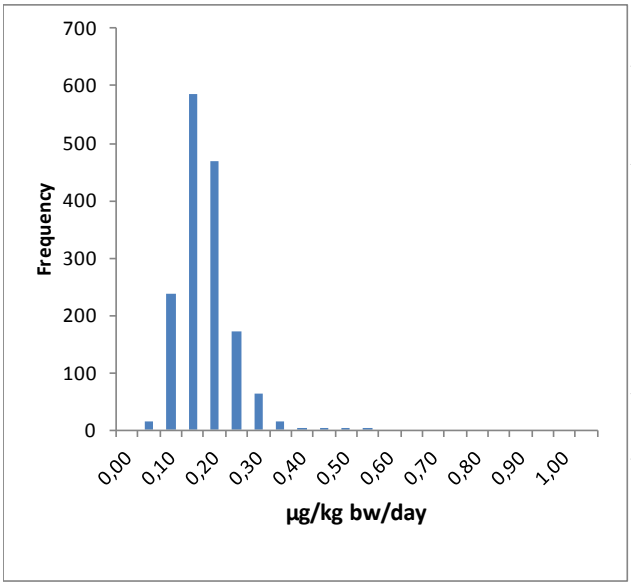
It is on the other hand in agreement with the cadmium exposure in the French adult population (0.16 µg/kg bw/day). For France the EFSA estimated an intake at 2.27 µg/kg bw/day, i.e. at the same level as for Denmark and similarly higher than the national French evaluation.

FIGURE 3
DISTRIBUTION OF CADMIUM INTAKE IN µG/KG BW/DAY IN THE GROUP OF CHILDREN (4-75 YEARS)



		µg/kg bw/day
Mean		0,31
sd		0,12
N		409
Percentiles	1	0,09
	5	0,14
	25	0,22
(median)	50	0,30
	75	0,37
	95	0,52
	99	0,67
Minimum		0,03
Maximum		0,97

FIGURE 4
DISTRIBUTION OF CADMIUM INTAKE IN µG/KG BW/DAY IN THE GROUP OF ADULTS (4-75 YEARS)

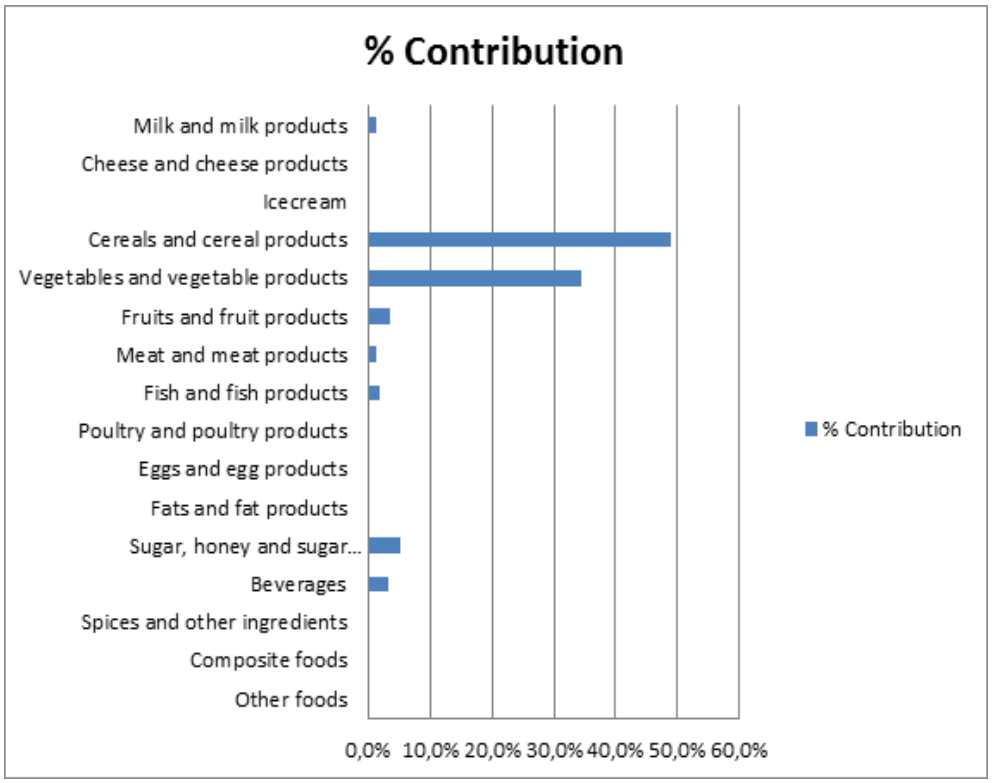


		µg/kg bw/day
Mean		0,15
sd		0,06
N		1565
Percentiles	1	0,05
	5	0,08
	25	0,11
(median)	50	0,15
	75	0,18
	95	0,26
	99	0,32
Minimum		0,02
Maximum		0,50

Cadmium intake from main food groups

Figure 5 shows the intake from different food groups. The food groups, which contributes most to cadmium intake are cereals and starch products (49%) and vegetables (34%). This is in concordance with the previous reporting period of 1998-2003.

FIGURE 5 INTAKE OF CADMIUM FROM MAIN FOOD GROUPS BY THE DANISH POPULATION (4-75 YEARS)



Conclusion

The dietary intake of cadmium in the Danish population (4-75 years) has been evaluated using occurrence and consumption data. The mean intake was calculated at 10.8 µg/day or 0.18 µg/kg bw/day corresponding to 50% of the TWI value at 2.5 µg/kg bw/week (=0.36 µg/kg bw/day) by EFSA in 2009. The intake of cadmium is at the same level as reported for the time period 1998-2003 (10 µg/day). However, the TWI value has in the meantime been lowered from 7 µg/kg bw/week to 2.5 µg/kg bw/week. Consequently, the margin of exposure compared to the new TWI value has decreased.

The food groups with the highest contribution to the dietary intake are cereals and starch products (49%) and vegetables and vegetable products (34%)."

7.3.2 Occupational exposure

According to the Danish Working Environment Agency [Jensen 2012] there are no recent monitoring data of the occupational exposure from cadmium.

The occupational use of cadmium is limited to uses in a few galvanizing factories and limited to production and reparation of material for air crafts. Exposure to cadmium can also occur during waste handling of electronic equipment and batteries containing cadmium.

Cadmium has been strongly regulated in the Danish occupational regulation with the result of highly limited and controlled use.

7.3.3 Human biomonitoring data

Available human biomonitoring data on cadmium from Denmark is limited to an investigation of cadmium levels in kidney and liver from Danes [Hansen *et al.* 2989]. The abstract of this investigation is presented below:

"To determine the cadmium exposure level in the Danish population, tissue samples of kidney and liver were collected over the period 1981 to 1987 at the Institutes of Forensic Medicine in Copenhagen, Odense and Aarhus. A total of 795 samples were collected, of which 143 were selected for analysis using, the criteria sudden violent death (accident, homicide or suicide). Cadmium concentrations in kidney cortex increased by age to a maximum of approximately 22 micrograms/g/g (w/w) in the age group 45-55 years and decreased in the older age group, while liver concentrations tended to increase throughout the entire lifespan. Cadmium concentrations in kidney cortex and liver were found significantly correlated. The findings are in good agreement with internationally published data, but lower than previously reported Danish concentration levels. "

8. Information on alternatives

Initiatives to substitute cadmium for dominating applications have been ongoing since about 1980 when the first bans on the use of cadmium in products were introduced. Thus for most applications, in particular plating, alloys, pigments and stabilizers many alternatives have been developed and adopted by the market. An overview based on Hansen et al. [2002] is presented in Table 22 below.

TABEL 22
OPTIONS FOR SUBSTTUTION OF CADMIUM (BASED ON HANSEN ET AL. 2002)

Application	Alternatives *2	Health and environmental classification of alternatives * 1
Plating	Zinc, aluminium, tin, nickel, silver, gold plating etc. depending on application.	Zinc/Zinc oxide: Pyr. Sol 1, Aquatic Acute 1, Aquatic Chronic 1 Aluminium: Not classified Tin: Not classified Nickel/nickel oxide: Carc. 2 , Skin Sens 1, STOT RE 1, Carc. 1Ai, Aquatic Chronic 4 Silver: Not classified
Silver-cadmium alloys	Silver-cadmium alloys are used for solders and jewellery with up to 30% cadmium in some types of jewellery [Drivsholm *et al.* 2000]. Many alternative solders exist including e.g. tin-silver solders. Alloys for jewellery may be replaced by pure silver.	Tin: Not classified Silver: Not classified
Copper-cadmium alloys, solders and other alloys	Alternatives depend on application: • Copper-Cadmium and alloys may be replaced by pure copper • Zinc-Cadmium alloys for anti-corrosion anodes may be replaced by aluminium anodes • Lead-Cadmium alloys for cable sheaths may be replaced by using other types of cable sheaths like PE/XLPE-sheaths, aluminium sheaths or normal lead sheaths.	Copper/copper oxide: Acute Tox. 4, Aquatic Acute 1, Aquatic Chronic 1 Aluminium: Not classified PE/XLPE: Not classified as material but additives could be. Lead/Lead oxide: Repr. 1A, Acute Tox. 4, STOT RE 2, Aquatic Acute 1, Aquatic Chronic 1, Repr 2;
Ni-Cd batteries	Nickel-metalhydride (NiMH) and lithium-ion-polymer batteries are well developed and able to substitute for NiCd batteries for all applications.	Nickel/nickel oxide: Carc. 2 , Skin Sens 1, STOT RE 1, Carc. 1Ai, Aquatic Chronic 4 Lithium: Water-react. 1, Skin Corr. 1B
PVC stabilizers	Depends on application. For indoor purposes substitutes have generally been calcium/zinc compounds.	Calcium/zinc compounds (e.g. stea-

Application	Alternatives *2	Health and environmental classification of alternatives * 1
	For outdoor purposes and other demanding applications like electrical cables/wires the alternatives have so far been stabilizers based on lead or organic tin compounds, but research/development based on calcium/zinc and organic compounds is on going	rates): Not classified Tin compounds: Considered non-toxic to toxic depending on the actual compounds [Christiansen *et al.* 2989].
Pigments	Many alternatives are available on the market. Ultimately, the choice is a matter of costs versus colour and other characteristics preferred such as weather resistance, torsion stability and brilliance.	It is not known which alternatives should be regarded as substitutes for cadmium. Therefore alternatives cannot be classified
Photovoltaic cells	Cadmium is used in modern thin-film cells based on cadmium-telluride, but not in traditional crystalline silicon cells.	Silicon: Not classified

*1 From [Hansen *et al.* 2002]

*2 Based on [EC 2008; MST 2009]

9. Overall Conclusions

9.1 Main issues

The knowledge available on cadmium and cadmium compounds is comprehensive.

According to WHO, cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen. The kidney is regarded as the critical target organ. Cadmium accumulates primarily in the kidneys, and its biological half-life in humans is 10–35 years. This accumulation may lead to renal tubular dysfunction, which results in increased excretion of low molecular weight proteins in the urine. This effect is generally irreversible.

Cadmium is a human carcinogen by the inhalation route. Epidemiological data from occupational settings confirm the lungs as being the primary target organ. Cadmium is not considered a carcinogen by ingestion.

Aquatic fresh and marine invertebrates are the organisms most sensitive to cadmium. The dissolved cadmium concentrations measured in some European waters (mainly rivers) exceed the threshold concentration producing adverse effects in the aquatic ecosystem.

Food is the dominant source of cadmium exposure in humans and accounts for approximately 90 per cent of the intake of the general, non-smoking population. Cadmium occurs in all food, but agricultural crops generally account for most of the intake. The mean intake was calculated at 10.8 µg/day or 0.18 µg/kg bw/day corresponding to 50% of the Tolerable Weekly Intake (TWI) value at 2.5 µg/kg bw/week (=0.36 µg/kg bw/day)that was established by EFSA in 2009.

The intake of cadmium is at the same level as reported for the time period 1998-2003 (10 µg/day). However, the TWI value has in the meantime been lowered by EFSA from 7 µg/kg bw/week to 2.5 µg/kg bw/week. Consequently, the margin of exposure compared to the new TWI value has decreased.

Cadmium in crops is due to uptake from soils and depends on the content of cadmium in soil and factors such as soil pH, salinity, humus content, crop species and varieties and the presence of zinc and other elements.

In Denmark, the dominant sources for contribution of cadmium to agricultural soils are the use of commercial fertilizers containing phosphate together with atmospheric deposition originating from industrial activities and waste incineration.

Although the use of cadmium in Europe is severely restricted global consumption has remained constant over the last 15 years. In this context it is important to note that cadmium is produced as a by-product to zinc. Reduced demand for cadmium will just consequently make cadmium cheaper and thereby financially more attractive to use in products for which its use is not restricted.

The dominant use of cadmium today is nickel-cadmium rechargeable batteries. Although effective recycling systems for these batteries exist, a significant portion are not collected, and should be assumed to be disposed of with solid waste by being incinerated or landfilled. The most important

applications for these batteries are assumed to be cordless power tools and large non-portable batteries for emergency back-up systems etc.

Most other uses not restricted are of a small order. In order to minimize emissions of cadmium in the longer term, it should be regarded as essential that other significant uses of cadmium not designed and operated in a closed circuit are discouraged. Surplus cadmium on the market should instead be immobilized and directed to permanent storage. This should be considered an important challenge to the international community for the future.

Alternatives to cadmium are well developed for most applications.

9.2 Data gaps

Important data gaps include:

- Up to date figures on applications of cadmium and consumption by application areas in Denmark, with a special focus on cadmium in batteries.
- Up to date figures on collection and recycling activities for cadmium in Denmark.
- Up to date figures on emission of cadmium to the environment for Denmark.

10. Abbreviations and acronyms

BEK	Bekendtgørelse (Statutory Order)
Bw	body weight
CAS	Chemical Abstracts Service
Cd	Cadmium
CLP	Classification, labelling and packaging of substances and mixtures (EU regulation)
CMR	Carcinogenic, Mutagenic or toxic to Reproduction
DEPA	Danish Environmental Protection Agency
DKK	Danske kroner (Danish currency)
DTU	Technical University of Denmark
EC	European Community
ECHA	European Chemicals Agency
EEC	European Economic Community
EFSA	European Food Safety Authority
ELV	End of Life Vehicles (EU regulation)
ESIS	ESIS (Europan chemical Substances information System)
EPA	Environmental Protection Agency
EU	European Union
EU27	European Union med 27 member states
FAO	United Nations Food and Agriculture Organization
HELCOM	Helsinki Commission - is the governing body of the Helsinki Convention for the protection of the Marine Environment of the Baltic Sea Area.
ICdA	The International Cadmium Association
JEFCA	Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives
LED	Light emitting diode
LDCs	Least developed countries
LOUS	List of undesirable substances
NiCd	Nickel-Cadmium (rechargeable batteries)
NiMH	Nickel MetalHydride (rechargeable batteries)
NOVANA	Danish National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment
OSPAR	The OSPAR-Convention covering the marine environment of the North-East Atlantic. OSPAR refers to the 2 conventions (the Oslo Convention and the Paris Convention), which in 1992 were unified into the OSPAR Convention.
P	Phosphate
PARCOM	Paris Commission - the governing body of the Paris Convention - reference is made to OSPAR
PBT	Persistent, bioaccumulative and toxic (chemical)
PBT	Polybutylene terephthalate
PE/XLPE	Polyethylene/cross-linked polyethylene

pH	A measure of acidity level (actually a measure of theactivity of the solvated hydrogenion
PIC	Prior Informed Concent - reference is made to the Rotterdam Convention
POP	Persistent Organic Pollutants - Reference is made to the Stockholm Convention
ppm	parts per million (e.g. mg/kg)
PRODCOM	EU statistical database on the production of manufactured goods. The term comes from the French "PRODuction COMmunautaire" (Community Production)
PROBAS	The database of the Danish Product Register
PRTR	Pollutant Release and Transfer Register
PTMI	Provisional Tolerable Monthly Intake
PVC	Polyvinyl chloride
REACH	REACH is the European Community Regulation on chemicals and their safe use. It deals with the **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances
RoHS	Restriction of Hazardous Substances (EU regulation)
TWI	Tolerable Weekly Intake
SVHC	Substances of Very High Concern
UNEP	United Nations Environmental Programme
UV	Ultraviolet (light)
WHO	World Health Organisation
vPvB	very Persistant very Bioaccumulative (chemical)

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Appendix 1: EU and Danish legislation

Chemicals are regulated via EU and national legislations, the latter often being a national transposing of EU directives.

There are four main EU legal instruments:

- Regulations (DK: Forordninger) are binding in their entirety and directly applicable in all EU Member States.

- Directives (DK: Direktiver) are binding for the EU Member States as to the results to be achieved. Directives have to be transposed (DK: gennemført) into the national legal framework within a given timeframe. Directives leave margin for manoeuvre as to the form and means of implementation. However, there are great differences in the room for manoeuvre between directives. For example, several directives regulating chemicals previously were rather specific and often transposed more or less word-by-word into national legislation. Consequently and to further strengthen a level playing field within the internal market, the new chemicals policy (REACH) and the new legislation for classification and labelling (CLP) were implemented as Regulations. In Denmark, Directives are most frequently transposed as laws (DK: love) and statutory orders (DK: bekendtgørelser).

  The European Commission has the right and the duty to suggest new legislation in the form of regulations and directives, which in turn have to be adopted via the ordinary legislative procedure (formerly known as the co-decision procedure) involving the Council of Ministers (always involved) and the European Parliament (excluded from a few policy areas, but involved in chemicals policy).

  New or recasted directives and regulations often have phase-in periods for the various provisions set-out in the legal text. In the following, we will generally list the latest piece of EU legal text, even if the provisions identified are not yet fully implemented. On the other hand, we will include still valid Danish legislation, e.g. the implementation of the cosmetics directive) even if this will be replaced with the new Cosmetic Regulation.

- Decisions are fully binding on those to whom they are addressed. Decisions are EU laws relating to specific cases. They can come from the EU Council (sometimes jointly with the European Parliament) or the European Commission. They can require authorities and individuals in EU Member States either do something or stop doing something, and can also confer rights on them. In relation to EU chemicals policy, decisions are e.g. used in relation to inclusion of substances in REACH Annex XVII (restrictions). This takes place via a so-called comitology procedure involving member state committees. Decisions are also used under the EU ecolabelling Regulation in relation to establishing ecolabel criteria for specific product groups.

- Recommendations and opinions are non-binding, declaratory instruments.

Apart from transposed EU directives, Danish legislation can to some extent regulate chemicals via various general or sector specific legislation, most frequently via statutory orders (DK: bekendtgørelser).

REACH and CLP

REACH and CLP are the overarching pieces of EU chemicals legislation regulating mainstream industrial chemicals. The below will briefly summarise the REACH and CLP provisions and give an overview of 'pipeline' procedures, i.e. procedures which may (or may not) result in an eventual in-

clusion under one of the REACH procedures. Further information on REACH and CLP can be found the web-site of the European Chemicals Agency (ECHA): http://echa.europa.eu/.

(Pre-)Registration
All manufacturers and importers of chemical substance > 1 tonne/year have to register their chemicals with the European Chemicals Agency (ECHA). Pre-registered chemicals benefit from tonnage and property dependent staggered dead-lines with the latest registration dead-line in 2018.

Evaluation
A selected number of registrations will be evaluated by ECHA and the EU member states. Evaluation covers assessment of the compliance of individual dossiers (dossier evaluation) and substance evaluations involving information form all registrations of a given substance to see if further EU action is needed on that substance, for example as a restriction.

Authorisation
Authorisation aims at substituting or limiting the manufacturing, import and use of substances of very high concern (SVHC). For substances included in REACH annex XIV, industry has to cease use of those substance within a given dead-line (sunset date) or apply for authorisation for certain specified uses within an application date.

Restriction
The 'safety net'. If the authorities assess that that risks to be addressed at the EU level are still in place despite the above mechanisms, limitations of the manufacturing and use of a chemical substance (or substance group) may be implemented. Restrictions are listed in REACH annex XVII, which has also taken over the restrictions from the previous legislation (Directive 76/769/EEC).

Classification and Labelling
The CLP regulation implements the United Nations Global Harmonised System (CLP) for classification and labelling of substances and mixtures of substances (formally known as 'preparations') into EU legislation. It further specifies rules for packaging of chemicals.

Two other classification and labelling provisions are:

1. **Harmonised classification and labelling** for a number of chemical substances. These classifications are agreed at the EU level and can be found in CLP Annex VI. In addition to newly agreed harmonised classifications, the annex has taken over the harmonised classifications in Annex I of the previous Dangerous Substances Directive (67/548/EEC); classifications which have been 'translated' according to the new classification rules.

2. **Classification and labelling inventory**. All manufacturers and importers of chemicals substances are obliged to classify and label their substances. If no harmonised classification is available, a self-classification shall be done based on available information according to the classification criteria in the CLP regulation. As a new requirement, these self-classifications should be notified to ECHA, which in turn publish the classification and labelling inventory based on all notifications received. There is no tonnage trigger for this obligation. For the purpose of this report, self-classifications are summarised in Appendix 2.

REACH and CLP - pipeline information
In addition to listing substance already addressed by the provisions of REACH (pre-registrations, registrations, substances included in various annexes of REACH and CLP, etc.), the ECHA web-site also provides the opportunity for searching for substances in the pipeline in relation to certain REACH and CLP provisions. These will be briefly summarised below:

Community Rolling Action Plan (CoRAP)
The EU member states have the right and duty to conduct REACH substance evaluations. In order to coordinate this work among member States and inform the relevant stakeholders of upcoming substance evaluations, a Community Rolling Action Plan (CoRAP) is developed and published, indicating who and when a given substance is expected to be evaluated.

Authorisation process; candidate list, Authorisation list, Annex XIV
Before a substance is included in REACH Annex XIV and thus being subject to Authorisation, it has to go through the following steps:

- It has to be identified as a SVHC leading to inclusion in the candidate list
- It has to be prioritised and recommended for inclusion in ANNEX XIV (Authorisation list)
- It has to be included in REACH Annex XIV following a comitology procedure decision

The candidate list (substances agreed to possess SVHC properties) and the Authorisation list are published on the ECHA web-site.

Registry of intentions
When EU member states and ECHA (when asked by the European Commission) prepare a proposal for:

- a harmonised classification and labelling
- an identification of a substance as SVHC
- a restriction

this is done as a REACH Annex XV proposal.

The 'registry of intentions' gives on overview of intensions in relation to Annex XV dossiers divided into:

- Current intentions for submitting an Annex XV dossier
- Dossiers submitted
- Withdrawn intentions and withdrawn submissions

for the three types of Annex XV dossiers.

Ecolabels
Eco-label schemes are voluntary schemes where industry can apply for the right to use the eco-label on their products if these fulfil the ecolabelling criteria for that type of product. An EU scheme (the flower) and various national/regional schemes exist. In this project we have focused on the three most common schemes encountered on Danish products.

EU flower
The EU ecolabelling Regulation lays out the general rules and conditions for the EU ecolabel; the flower. Criteria for new product groups are gradually added to the scheme via 'decisions'; e.g. the COMMISSION DECISION of 21 June 2007 establishing the ecological criteria for the award of the Community eco-label to soaps, shampoos and hair conditioners.

Nordic Swan
The Nordic Swan is a cooperation between Denmark, Iceland, Norway, Sweden and Finland. Criteria are agreed among the participating countries and implemented in national legislation.

In Denmark, the practical implementation of the rules, applications and approval process related to the EU flower and Nordic Swan is hosted by "Miljømærkning Danmark" (http://www.ecolabel.dk/).

Blue Angel (Blauer Engel)
The Blue Angel is a national German eco-label. More information can be found on: http://www.blauer-engel.de/en.

International conventions

OSPAR Commission
OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. It started in 1972 with the Oslo Convention against dumping. It was broadened to cover land-based sources and the offshore industry by the Paris Convention of 1974. These two conventions were unified, up-dated and extended by the 1992 OSPAR Convention. The new annex on biodiversity and ecosystems was adopted in 1998 to cover non-polluting human activities that can adversely affect the sea.

The fifteen Governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom. Finland is not on the western coasts of Europe, but some of its rivers flow to the Barents Sea, and historically it was involved in the efforts to control the dumping of hazardous waste in the Atlantic and the North Sea. Luxembourg and Switzerland are Contracting Parties due to their location within the catchments of the River Rhine.

The work of the OSPAR Commission is formally governed by the Rules of Procedure of the OSPAR Commission.

Work to implement the OSPAR Convention and its strategies is taken forward through the adoption of decisions, which are legally binding on the Contracting Parties, recommendations and other agreements. Decisions and recommendations set out actions to be taken by the Contracting Parties. These measures are complemented by other agreements setting out:

- issues of importance
- agreed programmes of monitoring, information collection or other work which the Contracting Parties commit to carry out.
- guidelines or guidance setting out the the way that any programme or measure should be implemented
- actions to be taken by the OSPAR Commission on behalf of the Contracting Parties

HELCOM - Helsinki Commission
The Helsinki Commission, or HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention.

In pursuing this objective and vision the riparian countries have jointly pooled their efforts in HELCOM, which is works as:

- an environmental policy maker for the Baltic Sea area by developing common environmental objectives and actions;

- an environmental focal point providing information about (i) the state of/trends in the marine environment; (ii) the efficiency of measures to protect it and (iii) common initiatives and positions which can form the basis for decision-making in other international fora;

- a body for developing, according to the specific needs of the Baltic Sea, Recommendations of its own and Recommendations supplementary to measures imposed by other international organisations;

- a supervisory body dedicated to ensuring that HELCOM environmental standards are fully implemented by all parties throughout the Baltic Sea and its catchment area; and

- a co-ordinating body, ascertaining multilateral response in case of major maritime incidents.

Stockholm Convention on Persistent Organic Pollutants (POPs)
The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have adverse effects to human health or to the environment. Exposure to Persistent Organic Pollutants (POPs) can lead serious health effects including certain cancers, birth defects, dysfunctional immune and reproductive systems, greater susceptibility to disease and even diminished intelligence. Given their long range transport, no one government acting alone can protect is citizens or its environment from POPs. In response to this global problem, the Stockholm Convention, which was adopted in 2001 and entered into force in 2004, requires Parties to take measures to eliminate or reduce the release of POPs into the environment. The Convention is administered by the United Nations Environment Programme and is based in Geneva, Switzerland.

Appendix 2: Self-classifications

The Classification & Labelling (C&L) Inventory database at the website of the European Chemicals Agency (ECHA) contains classification and labelling information on notified and registered substances received from manufacturers and importers. The database includes as well the harmonised classification. Companies have provided this information in their C&L notifications or registration dossiers. ECHA maintains the Inventory, but does not verify the accuracy of the information (ECHA, 2012).

CLASSIFICATION INFORMATION ON NOTIFIED AND REGISTERED SUBSTANCES RECEIVED FROM MANUFACTURERS AND IMPORTERS (C&L LIST)* [EKSEMPLER - IKKE KOMPLET]

CAS No	Substance name	Hazard Class and Category Code(s)	Hazard Statement Codes	Number of notifiers
513-78-0	cadmium carbonate	Acute Tox. 4	H302	28
		Acute Tox. 4	H312	28
		Acute Tox. 2	H330	13
		Acute Tox. 4	H332	28
		Muta. 2	H341	13
		Carc. 1B	H350	13
		Repr. 2	H361	13
		STOT RE 1	H372	13
		Aquatic Acute 1	H400	28
		Aquatic Chronic 1	H410	41
1306-19-0	cadmium oxide	Acute Tox. 3	H301	88
		Acute Tox. 2	H310	2
		Acute Tox. 1	H330	418
		Muta. 2	H341	418
		Carc. 1B	H350	418
		Repr. 2	H361	418
		STOT RE 1	H372	417
		STOR RE 2	H373	1
		Aquatic Acute 1	H400	408
		Aquatic Chronic 1	H410	418
1306-23-6	cadmium sulphide	Acute Tox. 4	H302	154
		Muta. 2	H341	154
		Carc. 1B	H350	154
		Repr. 2	H361	154
		STOT RE 1	H372	154
		Aquatic Chronic 4	H413	154
7440-43-9	Cadmium	Pyr. Sol. 1	H250	153
		Acute Tox. 3	H301	28
		Acute Tox. 2	H330	487
		Muta. 2	H341	487
		Carc. 1B	H350	487
		Repr. 2	H361	487
		STOT RE 1	H372	487
		Aquatic Acute 1	H400	397
		Aquatic Chronic 1	H410	487
10108-64-2	cadmium chloride	Acute Tox. 3	H301	107

CAS No	Substance name	Hazard Class and Category Code(s)	Hazard State-ment Codes	Number of notifiers
		Acute Tox. 2	H330	107
		Muta. 1B	H340	107
		Carc. 1B	H350	107
		Repr. 1B	H360	107
		STOT RE 1	H372	107
		Aquatic Acute 1	H400	105
		Aquatic Chronic 1	H410	107
10124-36-4	cadmium sulphate	Acute Tox. 3	H301	24
		Acute Tox. 2	H330	24
		Muta. 1B	H340	24
		Carc. 1B	H350	24
		Repr. 1B	H360	24
		STOT RE 1	H372	24
		Aquatic Acute 1	H400	24
		Aquatic Chronic 1	H410	24
10325-94-7	cadmium nitrate	Ox. Sol. 2	H272	25
		Acute Tox. 4	H302	29
		Acute Tox. 4	H312	29
		Acute Tox. 4	H332	29
		Carc. 1A	H350	1
		Aquatic Acute 1	H400	29
		Aquatic Chronic 1	H410	29
21041-95-2	cadmium hydrox-ide	Acute Tox. 4	H302	38
		Acute Tox. 4	H312	38
		Acute Tox. 4	H330	2
		Acute Tox. 4	H332	38
		Muta. 2	H341	2
		Carc. 1B	H350	2
		Repr. 2	H361	2
		STOT RE 1	H372	2
		Aquatic Acute 1	H400	38
		Aquatic Chronic 1	H410	40
69011-69-4	Cadmium, dross	Acute Tox. 2	H314	4
		Acute Tox. 4	H330	4
		Muta. 2	H341	4
		Carc. 1B	H350	4
		Repr. 2	H361	4
		STOT RE 1	H372	4
		Aquatic Chronic 1	H410	4
69012-21-1	Wastewater, cad-mium sulfate electrolytic, acid	Acute Tox. 3	H301	3
		Skin Sens. 1	H317	3
		Eye Dam. 1	H318	3
		Acute Tox. 2	H330	3
		Resp. Sens. 1	H334	3
		Muta. 1B	H340	3
		Carc. 1B	H350	3
		Repr. 1B	H360	3
		STOT RE 1	H372	3

CAS No	Substance name	Hazard Class and Category Code(s)	Hazard State-ment Codes	Number of notifiers
		Aquatic Chronic 1	H410	3
91053-44-0	Leach residues, cadmium cake	Acute Tox. 3 Skin Sens. 1 Eye Dam. 1 Acute Tox. 2 Resp. Sens. 1 Muta. 1B Carc. 1B Repr. 1B STOT RE 1 Aquatic Chronic 1	H301 H317 H318 H330 H334 H340 H350 H360 H372 H410	14 14 14 14 14 14 14 14 14 14

* Source : Search Classification and Labelling Inventory at http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

Appendix 3: Ecolabels

The use of cadmium is generally prohibited or restricted in criteria for Eco-labels. The table below gives an overview of how cadmium and cadmium compounds are addressed by the EU, Nordic and German eco-labelling schemes. It shows that the presence of cadmium and cadmium compounds is prohibited or strictly limited in the schemes for a long list of products such as plastics/coatings/coverings/building materials, dyes/pigments/additives, batteries/electronic equipment, paper packaging, furniture/textiles, tyres, cosmetics and toys.

ECO-LABELS TARGETING CADMIUM AND CADMIUM COMPOUNDS

Eco-label	Substances	Mixtures and articles	Document title
Nordic Swan	Cadmium	Dyes in professional products: May not be present	Nordic Ecolabelling of Car and boat care products
Nordic Swan	Cadmium	Batteries: Content may not exceed ≤ 1.0 ppm	Nordic Ecolabelling of Primary batteries
Nordic Swan	Cadmium	Washing machines: May not be added to the plastic	Nordic Ecolabelling of Washing machines
Nordic Swan	Cadmium	Floor coverings: May not be added	Nordic Ecolabelling of Floor coverings
Nordic Swan	Cadmium	Rechargeable batteries: Content may not exceed ≤ 5.0 ppm Battery chargers: May not be added to the plastic	Nordic Ecolabelling of Rechargeable batteries
Nordic Swan	Cadmium	Furniture and fitments: May not be added	Nordic Ecolabelling of Furniture and fitments
Nordic Swan	Cadmium	Textiles, skins and leather: May not be present	Nordic Ecolabelling of Textiles, skins and leather:
Nordic Swan	Cadmium	Dish washers: May not be added	Nordic Ecolabelling of Dish washers
Nordic Swan	Cadmium	Machines for parks and gardens: May not be present in plastic or surface treatment agents	Nordic Ecolabelling of Machines for parks and gardens
Nordic Swan	Heavy metals incl. Cadmium	Printing companies, printed matter, envelopes and other converted paper products:	Nordic Ecolabelling of Printing companies, printed matter, envelopes and other converted paper products
Nordic Swan	Cadmium	Writing instruments: May not be present	Nordic Ecolabelling of Writing instruments
Nordic Swan	Cadmium	Solid biofuel boilers: May not be present in surface treatment	Nordic Ecolabelling of Solid biofuel boilers

Eco-label	Substances	Mixtures and articles	Document title
Nordic Swan	Cadmium	De-icers: Total content may not exceed 0.8 mg/kg dry substance	Nordic Ecolabelling of De-icers:
Nordic Swan	Cadmium	Vehicle tyres: The quantity in ZiO may not exceed 0.01 %	Nordic Ecolabelling of Vehicle tyres
Nordic Swan	Cadmium	Outdoor furniture and play-ground equipment: Metal must not be plated with it	Nordic Ecolabelling of Outdoor furniture and playground equipment
Nordic Swan	Cadmium	Fabric cleaning products con-taining micro fibres: *May not be present in pig-ments, additives, metal coating and in plastic	Nordic Ecolabelling of Fabric cleaning products containing micro fibres
Nordic Swan	Cadmium	Stoves: May not be present in plating or coating of metals	Nordic Ecolabelling of Stoves
Nordic Swan	Cadmium	Candles: May not be added	Nordic Ecolabelling of Candles
Nordic Swan	Cadmium	Small houses, apartment build-ings and pre-school buildings: May not be present in chemical building components and in chemical substances in perma-nent building components	Nordic Ecolabelling of Small houses, apartment buildings and pre-school buildings
Nordic Swan	Cadmium	Toner cartridges: The content in total may not exceed 100 ppm	Nordic Ecolabelling of Toner cartridges
Nordic Swan	Cadmium	Cosmetic products: The content in total may not exceed 10 ppm in colouring agents	Nordic Ecolabelling of Cosmetic products
Nordic Swan	Cadmium	Toys: May not be present in colorants and additives added to plastic and rubber and in metals	Nordic Ecolabelling of Toys
Nordic Swan	Cadmium	Indoor paints and varnishes: May not be added	Nordic Ecolabelling of Indoor paints and varnish-es

Eco-label	Substances	Mixtures and articles	Document title
EU Flower	Cadmium	Wooden furniture: May not be present in halogenated organic binding agents, azidirin and polyaziridins as well as pigments and Additives used in the product	COMMISSION DECISION of 30 November 2009 on establishing the ecological criteria for the award of the Community eco-label for wooden furniture
EU Flower	Cadmium	Bed mattresses: Concentrations may not exceed 0.1 ppm	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for bet mattresses
EU Flower	Cadmium	Hard coverings: Concentrations may not exceed 0.1 % of weight of glaze	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for hard coverings
EU Flower	Cadmium	Wooden floor coverings: May not be present in halogenated organic binding agents, azidirin and polyaziridins as well as pigments and Additives used in the product	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for wooden floor coverings
EU Flower	Cadmium	Soaps, shampoos and hair conditioners: May not be present in the packaging	COMMISSION DECISION of 21 June 2007 on establishing the ecological criteria for the award of the Community eco-label for Soaps, shampoos and hair conditioners
EU Flower	Cadmium	Furniture: May not be present in surface treatment, materials and plastic. May not be detectable in leather furniture	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for furniture
EU Flower	Cadmium	Portable computers: May not be present in plastic parts and may not exceed 0.001 w% in batteries	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for portable computers
EU Flower	Cadmium	Indoor paints and varnishes: May not be added	COMMISSION DECISION of 13 August 2008 on establishing the ecological criteria for the award of the Community eco-label

Eco-label	Substances	Mixtures and articles	Document title
			for indoor paints and varnishes
EU Flower	Cadmium	Footwear: May not be present in the materials	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for footwear
EU Flower	Cadmium	Heat pumps: May not be used in the product	COMMISSION DECISION of 9 July 2009 on establishing the ecological criteria for the award of the Community eco-label for electrically driven, gas driven or gas absorption heat pumps
German Blue Angel	Cadmium	Sanitary Paper Products Colorants (pigments or dyes) containing mercury, lead, cadmium or hexavalent chromium compounds as constituents must not be used.	Basic Criteria for Award of the Environmental Label: Sanitary Paper Products RAL-UZ 5
German Blue Angel	Cadmium	Wallpapers and Woodchip Wall Coverings Colorants (i.e. pigments or dyes) containing mercury, lead, cadmium or chromium VI compounds as constituent parts must not be used. The heavy metal concentration in products according to para. 2 must be lower than the limiting concentrations (2mg/kg for cadmium).	Basic Criteria for Award of the Environmental Label: Wallpapers and Woodchip Wall Coverings promarily made of Recycled Paper RAL-UZ 35
German Blue Angel	Cadmium	Building Materials made of Waste Paper Colorants (i.e. pigments or dyes) containing mercury, lead, cadmium or chromium VI compounds as constituent parts must not be used.	Basic Criteria for Award of the Environmental Label : Building Materials made of Waste Paper RAL-UZ 36
German Blue Angel	Cadmium	Low-Emission Wood Products and Wood-Base Products The manufacturers of wood paints observing the Directive for Declaration of Wood Paint	Basic Criteria for Award of the Environmental Label : Low-Emission Wood Products and Wood-Base Products

Eco-label	Substances	Mixtures and articles	Document title
		Systems undertake with regard to the distinguished products: a) to do without the following ingredients: - asbestos - lead, cadmium and mercury compounds	RAL-UZ 38
German Blue Angel	Cadmium	Solar-Powered and Mechanical Products Solar-powered products and mechanical watches/clocks help to reduce the amounts of heavy-metals or pollutants contained in batteries. This particularly applies to cadmium used in accumulators.	Basic Criteria for Award of the Environmental Label : Solar-Powered Products and Mechanical Watches/Clocks and Torch-es RAL-UZ 47
German Blue Angel	Cadmium	Lithium Batteries Neither mercury nor cadmium may be contained in the lithium batteries.	Basic Criteria for Award of the Environmental Label : Lithium Batteries RAL-UZ 50
German Blue Angel	Cadmium	Low-Noise and Low-Pollutant Municipal Vehicles and Busses Except for impurities, priming and painting of the vehicles shall be done with coating materials free from paint raw materials (fillers, pigments, drying agents) which contain lead, chromium VI and cadmi-um compounds.	Basic Criteria for Award of the Environmental Label: Low-Noise and Low-Pollutant Municipal Vehi-cles and Busses RAL-UZ 59
German Blue Angel	Cadmium	Cadmium-free Hard Solders The products must not contain any cadmium as alloying metal. Raw-material impurities and production-induced impurities shall be permissible up to a maximum content of 0.01 weight per cent for phospho-rous-containing hard solders and up to 0.03 weight per cent for all other hard solders	Basic Criteria for Award of the Environmental Label : Cadmium-free Hard Sol-ders RAL-UZ 68
German Blue Angel	Cadmium	Colorants (pigments or dyes) containing Printing and Publi-cation Papers primarily made of waste paper mercury, lead, cadmium or hexavalent chromium compounds as con-stituents must not be used.	Basic Criteria for Award of the Environmental Label : Printing and Publication Papers primarily made of waste paper RAL-UZ 72

Eco-label	Substances	Mixtures and articles	Document title
German Blue Angel	Cadmium	Energy-saving Refrigerators and Freezers If the plastic parts used are made from primary plastics they shall not include any cadmium and lead-containing additives. If recycled plastics are used these recycled plastics may include up to 75 ppm of cadmium and lead-containing additives.	Basic Criteria for Award of the Environmental Label : Energy-saving Refrigerators and Freezers RAL-UZ 75
German Blue Angel	Cadmium	Workstations Computers If the plastic parts used are made from primary plastics they shall not include any cadmium and lead-containing additives. If recycled plastics are used these recycledplastics may include up to 75 ppm of cadmium and lead-containing additives.	Basic Criteria for Award of the Environmental Label : Workstations Computers RAL-UZ 78
German Blue Angel	Cadmium	Printers Batteries and accumulators must not contain any of the heavy metals lead, cadmium or mercury. Excluded from this are technically unavoidable impurities. Toners and inks must not contain any materials that contain mercury, cadmium, lead, or chromium VI compounds as constituents. The photoconductor drums must not contain selenium, lead, mercury or cadmium or any of their compounds as constituents. Cadmium-containing components or materials must not be used for remanufacturing.	Basic Criteria for Award of the Environmental Label : Printers RAL-UZ 85
German Blue Angel	Cadmium	Low-Energy Hand Driers No cadmium-plated parts may be used.	Basic Criteria for Award of the Environmental Label : Low-Energy Hand Driers RAL-UZ 87
German Blue Angel	Cadmium	Rechargeable Alkaline/ Manganese Batteries Neither cadmium nor mercury may be contained in the batter-	Basic Criteria for Award of the Environmental Label : Rechargeable Alkaline/Manganese Batteries

Eco-label	Substances	Mixtures and articles	Document title
		ies. Exempted from this rule are impurities of up to 10 ppm for cadmium and 5 ppm for mercury.	RAL-UZ 92
German Blue Angel	Cadmium	Portable Computers With the exemption of technically unavoidable impurities batteries and accumulators must not contain any lead, cadmium or mercury. Such impurities must not exceed the limiting values as specified in the EU Battery Directives (91/157/EEC and 98/101/EEC)	Basic Criteria for Award of the Environmental Label : Portable Computers RAL-UZ 93
German Blue Angel	Cadmium	Fax Machines, Telecopiers and Combined Fax Machines - batteries/accumulators Provided that the appliance is equipped with batteries, such batteries must not contain the heavy metals cadmium, lead or mercury. Toner, ink and ink ribbons must not include any substances containing compounds of mercury, lead, cadmium or chromium VI as constituent parts. The photoconductor drums must not contain any lead, cadmium or mercury as constituent parts. No cadmium plated substances or parts may be used for reprocessing.	Basic Criteria for Award of the Environmental Label : Fax Machines, Telecopiers and Combined Fax Machines RAL-UZ 95
German Blue Angel	Cadmium	Household Dish Washers Varnishes containing cadmium, lead or chromium VI must not be used for the painting of cases. Excluded are natural or production induced impurities of up to 100ppm for cadmium and chromium VI and up to 200 ppm for lead.	Basic Criteria for Award of the Environmental Label : Household Dish Washers RAL-UZ 97
German Blue Angel	Cadmium	Mobile Phones Lead and cadmium as well as their compounds must not be added to the plastics and coatings used. Electronic Components Cadmium, mercury as well as	Basic Criteria for Award of the Environmental Label : Mobile Phones RAL-UZ 106

Eco-label	Substances	Mixtures and articles	Document title
		beryllium and their compounds must not be used. Batteries and accumulators must not contain any lead, cadmium or mercury	
German Blue Angel	Cadmium	Electric Installation Equipment and Systems Equipment and systems should have lead-free, nickel-free and cadmium-free contact and fuse element materials. Plastics forming case and design parts must be free from additives containing cadmium and arsenic. Contact materials must not contain any cadmium, nickel nor lead as alloy components. Fuse elements in fuse links must not contain any lead or cadmium, not even as alloy components. Electroplated metal and plastic parts must be free from substances such as chromium-(VI)-compounds or cadmium.	Basic Criteria for Award of the Environmental Label : Electric Installation Equipment and Systems RAL-UZ 107
German Blue Angel	Cadmium	Photovoltaic Products If the appliances are equipped with rechargeable batteries the applicant shall undertake to only use cadmium-free batteries in accordance with the Batteriegesetz (BattG) (German Battery Act) and include a clear notice requiring the use of a cadmium-free exchange battery into the product description.	Basic Criteria for Award of the Environmental Label : Photovoltaic Products RAL-UZ 116
German Blue Angel	Cadmium	Mattresses Declaration from the Textile Suppliers relating to Dyes and Pigments used in the Textiles: "We hereby confirm that the textiles do not contain dyes and pigments that contain cadmium, mercury, lead or nickel."	Basic Criteria for Award of the Environmental Label : Mattresses RAL-UZ 119

Eco-label	Substances	Mixtures and articles	Document title
German Blue Angel	Cadmium	Textiles The following heavy metals must not exceed the amounts given in the table - Cadmium: 0,1 mg/kg (textiles for infants) and 0.1 mg/kg (other textiles).	Basic Criteria for Award of the Environmental Label : Textiles RAL-UZ 154

Survey of cadmium and cadmium compounds

A survey has been performed for cadmium and cadmium compounds, which are listed on the Danish EPA's List of Undesired Substances (LOUS). Cadmium and cadmium compounds are highly toxic to human health and the environment. Cadmium is classified as a human carcinogen and is highly toxic to kidneys, the skeletal and respiratory systems. This survey gives an updated status of the current legislation, manufacture and use, waste management, effects on environment and human health and information on alternatives.

The major use of cadmium and cadmium compounds in Denmark and EU are in nickel-cadmium batteries, which are estimated to account for >80% of the total use. Apart from nickel-cadmium batteries the use of cadmium in EU is generally severely restricted. In Denmark the use of cadmium in nickel-cadmium batteries has decreased markedly during the latest years. Alternatives to cadmium are well developed and implemented for most uses.

Cadmium is assimilated in the environment due to the presence of cadmium in phosphate fertilisers and deposition from industrial activities and waste incineration. Both sources have been reduced significantly in Denmark singe the 1980'ies. Food is the dominant source of cadmium exposure of humans and accounts for approximately 90% of the intake for non-smokers. Cadmium in agricultural crops account for most of the intake. In certain European waters the dissolved cadmium concentrations exceed the threshold concentration for causing adverse effects in aquatic organisms.

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