**Hazardous Substances Series**

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# Cadmium

OSPAR Commission
2002 (2004 Update)

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

*La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.*



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# EXECUTIVE SUMMARY

Cadmium is a metallic element which in this form is rarely found in the environment. It occurs in the form of salts and the mobility in the environment and the effects on the ecosystem depend to a great extent on the nature of these salts in combination with other elements such as oxygen, chlorine or sulphur. The zinc-cadmium ratio is very important as the toxicity and accumulation of cadmium increase significantly due to zinc deficiency. Low levels of cadmium can produce long-term adverse effects, especially in animals and humans. Cadmium was included in 1998 in the OSPAR List of Chemicals for Priority Action.

Cadmium is used in the production of batteries, in intermediates and catalysts for electroplating, in pigment in paint, in stabiliser for plastic, in photographical processes and in dyes. More than 80% of the global production of cadmium in 1998 was derived from mining, smelting and refining of zinc. The rest was recovered in secondary processes whilst recycling cadmium from products. In 1998, primary production of cadmium in seven OSPAR states amounted to almost 5000 tonnes per year. Direct and riverine inputs of cadmium contributed 50 tonnes to the maritime area. Atmospheric emissions were 66 tonnes and the atmospheric inputs contributed 60 tonnes to the maritime area. Dredged material dumped into, or relocated in the maritime area contained 39 tonnes. Important sources of cadmium are primary iron and steel industry, non-ferrous industry, road transport, combustion of fuel in power plants, commercial, domestic and industrial combustion processes and other sources such as extraction of fossils, solvent use, waste treatment and disposal, and agriculture.

Sediments in lakes and rivers contain up to 5 mg Cd per kg. Marine sediments contain 0,03-1,0 mg/kg. Cadmium concentrations in rivers have been found at levels of 10-100 ng/l and in seawater 5-20 ng/l. Cadmium concentrations in marine organisms are usually higher than in fresh water organisms. The same pattern occurs in older and juvenile organisms. Cadmium is liable to bioaccumulate in liver and kidney of vertebrates. Higher cadmium residues in biota are generally associated with industrial and urban sources. Up to 1996 there have been significant decreases of cadmium concentrations in mussels at the Netherlands', Norwegian, Scottish and French coast. However an increase has been detected at the south coast of Portugal (1,3-3,1 mg/kg dw). Elevated cadmium levels have been detected in liver and kidney of pelagic seabirds and mammals such as white-beaked dolphins and pilot whales.

Action so far has been mainly carried out in several international forums such as OECD, EC and OSPAR; the latter two having established a suite of regulations addressing cadmium. A risk assessment for cadmium under the EC existing substances regulation is currently being carried out. Cadmium and its compounds are included in the list of priority substances under the EC Water Framework Directive as priority hazardous substances.

The action recommended is: to assess the need for further action in non-ferrous metal production and processing and the secondary iron and steel industry; to develop regulations for the management of wastes and toxic tailing spills from mining activities and to consider financial incentives to support the substitution of cadmium in products; to promote EC action on revising Council Directive 91/157/EEC and Commission Decision 1999/51/EC in order to ban the marketing and use of NiCd batteries; to focus on recycling campaigns for batteries and solar cells including the participation of consumers; to promote substitution in other products and review the actions in the EC risk assessment report on cadmium when it becomes available; to pay sufficient attention to the levels of cadmium authorised from emissions of IPPC-related installations for waste disposal; to review environmental assessments and controls imposed on wastes arising from mining activities; to invite the EC to consider to ban the import and marketing of products; to invite the EC to consider development of guidance on the use of sewage in agriculture and the adoption of common rules on the cadmium content of phosphate fertilisers in the EC; and to ask other relevant international forums to take account of this background document.

A monitoring strategy for cadmium has been added to this background document.

## RÉCAPITULATIF

Le cadmium est un élément métallique, que l'on trouve rarement sous sa forme métallique dans l'environnement. Il se présente sous la forme de sels, et sa mobilité dans l'environnement ainsi que ses effets sur l'écosystème dépendent dans une large mesure de la nature de ces sels et de leur combinaison avec d'autres éléments tels que l'oxygène, le chlore ou le soufre. La proportion zinc-cadmium est très importante car la toxicité et l'accumulation du cadmium augmentent significativement avec la carence en zinc. De faibles teneurs en cadmium peuvent avoir des effets sur le long terme, surtout chez les animaux et chez l'homme. Le cadmium est inscrit depuis 1998 sur la Liste OSPAR des produits chimiques devant faire l'objet de mesures prioritaires.

Le cadmium est utilisé pour fabriquer des piles électriques, dans les produits intermédiaires et les catalyseurs dans la galvanoplastie, dans les pigments des peintures, dans les stabilisateurs des matières plastiques, dans les procédés de photographie et dans les teintures. En 1998, plus de 80% de la production mondiale de cadmium a été tirée des mines de zinc, ainsi que des fonderies de zinc et de son raffinage. Le reste a été obtenu par des procédés secondaires, grâce au recyclage du cadmium récupéré sur des produits. En 1998, dans sept des Etats d'OSPAR, la production annuelle primaire de cadmium représentait près de 5 000 tonnes. Les apports directs et fluviaux de cadmium à la zone maritime se sont élevés à 50 tonnes. Les émissions atmosphériques ont été de 66 tonnes, et les apports atmosphériques à la zone maritime se sont élevés à 60 tonnes. Les matériaux de dragage immergés dans la zone maritime ou transférés d'un point à un autre de celle-ci en contenaient 39 tonnes. Les sources importantes de cadmium sont l'industrie sidérurgique de première fusion, l'industrie des métaux non ferreux, les véhicules automobiles, le brûlage du combustible dans les centrales électriques, le brûlage dans les foyers domestiques et dans l'industrie, ainsi que d'autres sources telles que l'extraction des combustibles fossiles, l'utilisation des solvants, le traitement et l'élimination des déchets et l'agriculture.

La teneur en cadmium dans les sédiments lacustres et fluviaux peut atteindre 5 mg Cd par kg. Dans les sédiments marins, les teneurs se situent entre 0,03 et 1 mg/kg. Dans les fleuves, l'on a constaté des teneurs en cadmium se situant entre 10 et 100 ng/l, et entre 5 et 20 ng/l dans l'eau de mer. Chez les organismes marins, les teneurs en cadmium sont en général plus fortes que chez les organismes vivant en eau douce. Le profil est le même, qu'il s'agisse d'organismes âgés ou d'organismes juvéniles. Le cadmium est susceptible de s'accumuler biologiquement dans le foie et dans les reins des vertébrés. Dans le milieu vivant, les hautes teneurs en résidus de cadmium sont en général associées à des sources industrielles et urbaines. Jusqu'en 1996, l'on a observé des baisses significatives des teneurs en cadmium dans les moules du littoral des Pays-Bas, de la Norvège, de l'Ecosse et de la France. En revanche, l'on a décelé une augmentation sur la côté sud du Portugal (1,3 à 3,1 mg/kg du poids sec). De hautes teneurs en cadmium ont été détectées dans le foie et dans les reins des oiseaux de mer et des mammifères pélagiques tels que les dauphins à bec blanc et les globicéphales noirs.

Jusqu'à présent, les mesures ont pour l'essentiel été prises dans le contexte de plusieurs instances internationales, telles que l'OCDE, la Communauté européenne et OSPAR, ces deux dernières ayant mis en place une série de règlements visant le cadmium. L'on procède à l'heure actuelle à une évaluation des risques suscités par le cadmium dans le cadre du Règlement communautaire européen visant les substances existantes. Le cadmium et ses composés sont inscrits sur la liste des substances prioritaires de la Directive communautaire européenne cadre relative à l'eau, dans la catégorie des substances dangereuses prioritaires.

Les mesures recommandées sont les suivantes : juger de la nécessité de nouvelles mesures visant la production et la transformation des métaux non ferreux ainsi que l'industrie sidérurgique de deuxième fusion ; élaborer des règlements sur la gestion des déchets et les chutes de refus toxiques dans l'industrie minière et considérer des incitations financières à la substitution du cadmium dans les produits ; encourager le remaniement de la Directive 91/157/CEE du Conseil et la Décision 1999/51/CE de la Commission, afin d'interdire la commercialisation et l'utilisation des piles au NiCd ; mettre l'accent sur

les campagnes de recyclage des piles et des cellules solaires, ceci avec la participation des consommateurs ; encourager la substitution dans d'autres produits et examiner les mesures inscrites dans le Rapport communautaire européen d'évaluation des risques du cadmium, lorsque ce dernier sortira ; accorder une attention suffisante aux teneurs en cadmium autorisées dans les émissions des installations d'élimination des déchets, tombant sous le coup de la directive IPPC ; réexaminer les évaluations environnementales et les règlements imposés pour les déchets des activités minières ; inviter la CE à envisager d'interdire l'importation et la commercialisation des produits ; inviter la CE à considérer l'élaboration d'une orientation sur l'utilisation des boues des égouts dans l'agriculture ainsi que l'adoption de règles communes applicables à la teneur en cadmium dans les engrais aux phosphates dans la CE ; et demander à d'autres instances internationales compétentes de tenir compte du présent document de fond.

Une stratégie de surveillance sur le cadmium a été ajoutée à ce document de fond.

# 1. INTRODUCTION

Cadmium is a metallic element belonging to group II of the Periodic Table (atomic number: 48, and relative atomic mass: 112,40). It is a soft silver-white metal, but the metallic form is rarely found in the environment. Some rare cadmium minerals are known, such as Greenockkite (CdS) and Hawlegite, Cadmoisite (CdSe), Monteponite (CdO) and Otavite (CdCO3), but concentrations of commercial interest are found in the deposits of zinc, lead and copper. Therefore, it is invariably recovered as a by-product of these ores and not as the principal product of any mine.

Cadmium can form a number of salts and both, its mobility in the environment and the effects on the ecosystem depend to a great extent on the nature of these salts in combination with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulphur (cadmium sulphide). Metallic Cd and CdO powder are less harmful in the environment than soluble $Cd^{2+}$. However, metallic Cd and CdO powder transform in the environment to the toxic $Cd^{2+}$ (RAR, 2001). These compounds are all stable solids that do not evaporate, although cadmium is often found as part of small particles present in air. Some cadmium salts, such as the sulphide, carbonate and oxide are particularly insoluble in water; these forms can be converted to water-soluble salts in nature.

Different salts of cadmium are utilised for different industrial uses:

- cadmium oxide: used in batteries, and as an intermediate and catalyst in electroplating;
- cadmium sulphide: used as a pigment in paint;
- cadmium sulphate: used as an intermediate in electroplating;
- cadmium stearate: used as a plastic stabiliser; and
- cadmium chloride: used in photography and in dyes.

The largest source of cadmium released to the atmosphere is from the burning of fossil fuels (such as coal or oil) or from the incineration of municipal waste. Some heavy metals (including lead, cadmium, mercury, and arsenic) may partially vaporise and leave the combustion unit with the flue gases. Cadmium may also escape into the air from zinc, lead, or copper smelters. It can enter into water as a result of the disposal of domestic waste water or industrial effluents. Fertilisers often contain some cadmium.

The amount of cadmium needed to cause an adverse effect in an exposed person depends on the chemical and physical form of the element. In general, cadmium compounds that dissolve easily in water (e.g. cadmium chloride), or those that can be dissolved in the body (e.g. cadmium oxide), tend to be more toxic than compounds that are very hard to dissolve (e.g. cadmium sulphide).

Cadmium and zinc are found together in natural deposits and possess similar structure and functions. The zinc-cadmium ratio is very important, as cadmium toxicity and storage are greatly increased with zinc deficiency. Zinc protects against tissue damage from cadmium. Beneficial effects from cadmium are not known and cadmium can cause a number of adverse health effects. It competes with zinc for chemical bonds and can therefore interfere with some of zinc's essential functions, may inhibit enzyme reactions and thus the utilisation of nutrients. Cadmium may act as a catalyst in oxidation reactions, which can generate damage of tissue by free radicals.

Low levels of cadmium can produce long-term adverse effects. Once ingested, cadmium cannot easily be excreted from the body and accumulates, usually in the kidneys and liver. Cadmium toxicity causes kidney and liver dysfunction, brittle bones, and adverse effects on reproduction and survival. Kidneys are responsible for calcium levels in the blood. When cadmium levels rise, kidney tubules fail and calcium levels drop. To compensate, the body "borrows" calcium from bones causing bone decalcification. A few studies show that younger animals absorb more cadmium and are more likely to lose bone and bone strength than adults. Animal studies also indicate that more cadmium is absorbed into the body if the diet is low in calcium, protein, or iron, or is high in fat (ATSDR, 1999). This can be a severe problem in adults and especially in mammals during lactation.

# 2. IDENTIFICATION OF MAIN SOURCES OF CADMIUM

## 2.1 Natural and anthropogenic sources

### *2.1.1 Natural sources and background concentrations*

Many substances, such as cadmium, occur naturally in the environment and it is therefore important to distinguish between natural concentrations and fluxes of these substances and the extent to which these are incremented by human activities. Such distinctions, although often difficult to make, are essential if informed decisions are to be made regarding the management of contaminants.

Volcanic activity is an important natural source of the release of cadmium to the atmosphere. The annual global flux from this source has been estimated to be 820 tonnes (Nriagu, 1989). Deep-sea volcanism is also a source of the release of cadmium to the environment, but the role of this process in the global cadmium cycle still remains to be quantified. Levels of up to 4,5 mg/kg have been found in volcanic soils (Korte, 1983), but higher levels are present in sedimentary rocks; marine phosphates often contain about 15 mg/kg (GESAMP, 1984). Marine black shales and slates have frequently been found to contain abnormally high concentrations of cadmium (<240 mg/kg) (OECD, 1994).

Cadmium present in various types of rocks and soils is widely distributed in the earth's crust, in non-volcanic areas, at average concentrations ranging from 0,1 to 0,2 mg/kg of soil (GESAMP, 1984; Laane, 1992). In exceptional case, values of 1 mg/kg in soil have also been found (OECD, 1994). This metal is commonly associated to zinc, and occurs naturally in zinc, lead and copper ores, which are the main deposits of cadmium. These deposits can reach ground and surface waters, especially when in contact with soft, acidic waters.

Typical concentrations in remote and selected parts of the OSPAR area are used as Background/Reference Concentrations (BRCs). For naturally occurring substances the BRC is the range of concentrations that would be anticipated to be present in the environment in the absence of any human activity. Obviously, nowadays it is virtually impossible to present a definitive value for the background concentration of natural stable compounds, which can be transported by wind, water and biota.

Table 1 summarises available BRCs for cadmium in seawater, sediments and biota (mussel tissue). In this respect it should be noted that data from Laane (1992), in Table 1, correspond to the North Sea before industrialisation.

**Table 1 Range in Background/Reference Concentrations of cadmium for fine-grained marine sediments, seawater and blue mussel within the OSPAR area**

| Compartment | Specifications | Concentration | Reference |
|---|---|---|---|
| Sea water (µg/l) | | ≤ 0,1 | Korte, 1983 |
| | | 0,005-0,025 | OSPAR/QSR, 2000 |
| | | 0,004±0,009 | Laane, 1992 |
| Marine sediments (mg/kg) | | 0,007-0,04[1] | OSPAR/QSR, 2000 |
| | | 0,03-1 | Korte, 1983 |
| | Wadden Sea | 0,5 ±0,01 | Laane, 1992 |
| | Norwegian coast | 0,08±0,02<br>0,013[1] | Laane, 1992<br>Laane, 1992 |
| River and lake sediments (mg/kg) | | Up to 5 | Korte, 1983 |
| Atmospheric ($ng/m^3$) | | 1 | WHO, 1992 |
| | | 0,2 | Laane, 1992 |
| | Rural area | 0,1-0,5 | Jensen and Bro-Rasmunsen, 1992 |
| Soil (mg/kg) | | 0,2-0,4 | WHO, 1992 |
| | | 0,1 to 1 | OECD, 1994 |
| Biota (mg/kg ww) | Blue mussel (M. edulis) | 0,07-0,11 | OSPAR/QSR, 2000 |
| | Mussels (Mytilus sp.) | <0,2[2] | Laane, 1992 |

## 2.2 Anthropogenic sources

Major anthropogenic sources of cadmium in the environment are associated with the production and processing of cadmium. Solid wastes from non-ferrous metal production and the manufacture of cadmium-containing articles, as well as ash residues from both fuel and waste incineration, are significant sources of environmental pollution.

Industrial sectors with the potential to release of cadmium into the environment, can be categorised as follows:

- activities related to primary production:
  - metallurgic processes (iron and steel production, smelting and refining of zinc, lead and copper bearing ores, melting and pouring of cadmium metal);
- activities related to secondary production:
  - the use of cadmium related products (batteries, coatings, pigments, stabilisers and alloys) does not result in direct releases of cadmium to the environment. However, manufacture and disposal of these products have a potential for releasing cadmium to the environment. This includes the following:
    - chemical industry: chemicals used in synthesis (intermediates, laboratory chemicals, raw material for the production of other cadmium containing chemicals and by-product in the production of zinc containing chemicals);
    - fabrication of metal, alloys or plated steel for electrical/electronic engineering industry. Cadmium alloy products are used as conductive and electroplating agents for coating

1 Metal ratio (Al * $10^{-4}$). The aluminium (Al) normalisation (e.g. Windom et al., 1989) is based on the fact that there are natural ratios between trace metals and Al that exist in the absence of any human influence. Since Al is a major component of clays its concentration is assumed always to be a natural concentration.

2 mg/kg dw.

telephone cables, fire alarms, high pressure/temperature bearings, starting switches, aircraft relays, light duty circuit breakers, low temperature solder, and jewellery, etc;

- manufacture of nickel-cadmium batteries for use in portable telephones, convenience appliances and vented cells used in aeroplanes, helicopters and stand-by power and lighting;
- polymer industry (stabilisers; also for PVC);
- paints, lacquers, varnished industry, ceramic, glass and related industry (colouring agents, filters and reprographic agents); and

- activities related to recycling of cadmium containing products:
  - cadmium recycling plants (recovery of metal by processing scrap).

Other releases of cadmium arise from diffuse sources, e.g. fossil fuel combustion, fertiliser application and sewage sludge disposal.

## 2.3 Activities related to Primary Production

### *2.3.1 Introduction*

According to WS Atkins (1998) relevant losses of cadmium during production processes occur only to the atmosphere and are negligible compared with the losses to air from, for example, stabiliser production (RAR, 2001).

Table 2 shows data which reflects the evolution of the production of refined cadmium metal in some OSPAR Contracting States during the last fifteen years. The price of cadmium on the world market is determined by supply and demand, and regulated by the US government in relation to the price of zinc. It showed an increasing trend until 1989. In 1979, the price was approximately 1,00 $/lbs, but in 1988 it was almost eight times higher. This increase has been attributed to tight supply, speculative trading and high demand for nickel-cadmium batteries. In 1993, prices were about 0,5 $/lbs. Market fluctuations and volatile prices have an important influence on secondary production and recycling prospects.

**Table 2 Cadmium production and prices in different years in OSPAR countries (in tonnes)[3]**

| Country | 1985[4] | 1990[5] | 1993[5] | 1998[6] |
|---|---|---|---|---|
| Belgium | 1293 | 1750[4]-1958 | 1573 | 1145[2]-1318 |
| Finland | 564 | 591[5]-568 | 785 | 550 |
| France | 365 | 188 | 139 | 177 |
| Germany | 1095 | 973 | 1069 | 1150 |
| Netherlands | 598 | 590 | 526 | 739 |
| Norway | 164 | 286 | 213 | 270 |
| Spain | 268 | 262-344[4 7] | 329 | 320 |
| United Kingdom | 370 | 438 | 458 | 440 |
| **Total** | **4717** | **5263** | **5092** | **4964** |
| Price ($/lbs) | 1,21 | 7,90[8]-3,38 | 0,45 | 0,28 |

3 Source: World Bureau of Metal Statistics in OECD, 1994.
4 WBMS from Roskill, 1995.
5 EUPHEMET, 2000.
6 Plachy, 1998.
7 Data for 1991.
8 Data for 1988.

### 2.3.2 Non-ferrous industry

Cadmium is a naturally occurring constituent in all zinc, lead and copper ores, and is closely linked to the production of those non-ferrous metals. Consequently, cadmium is produced mainly as a by-product from mining, smelting, and refining sulphide ores of zinc, and to a lesser degree, lead and copper. More than 80% of the world's cadmium production in 1998 was derived from mining, smelting and refining of zinc (EUPHEMET, 2000). Total releases in 1997 to air, water and soil were 41, 40-60 and 419 tonnes, respectively.

### 2.3.3 Toxic tailing spills

Toxic tailing spills are hazardous accidents associated with mining activities. On 25 April 1998, the tailing dam of Boliden company at the Aznalcóllar mine (70 km north of Doñana National Park, South-west Spain) collapsed and the valleys of the Agrio and Guadiamar rivers were flooded with more than 5 million $m^3$ of toxic sludges, dissolved in acidic water (ca. pH2), heavily polluting the downstream areas with heavy metals, including amongst others cadmium, arsenic, lead, copper and zinc. The bulk of the sludge was removed during the four months after the collapse, but about 0,1 to 5 wt % remained mixed with the uppermost layer of the soil. These very hazardous accidents led to heavy metal pollution processes that could be avoided by greater cooperation between industry and authorities on security measures.

In another accident related to the same company, a million cubic metres of copper contaminated water was released into the Vassara River in northern Sweden, on 9 September 2000, following the collapse of a mining waste dam at the Aitik copper mine. The spill is Sweden's biggest mine waste dam collapse to date. Aitik, an open pit copper mine, was established in 1968 near the town of Gallivare, north of the Arctic Circle in Sweden and is one of Europe's largest copper mines.

### 2.3.4 Iron and steel industry

Cadmium emissions may occur at several stages in the production of iron and steel, including both primary and secondary steel making. Although the cadmium levels in most input materials for steel making processes are quite low, the volumes of materials handled are very high and there is a potential for significant cadmium releases to the environment. Current control devices capture much of the possible emissions of cadmium to air and discharges to water, e.g. electric arc furnace (EAF) dust, bag house dust and filter cakes from the wet scrubbers (OECD, 1994).

In the Netherlands a decrease of emissions of more than 50% has been estimated from 1985 to 1996. In Denmark "the emissions from the production of iron and steel have been reduced drastically". As a rough estimate, a decrease of 35-40% in cadmium emissions from industrial sources have been achieved (ERL in EUPHEMET, 2000).

In general, it is expected that there will be an increase in the consumption of iron and steel by industrialised countries. The share of OECD countries in world steel consumption increased from 49% in 1980 to 58% in 1998 (in particular, the construction and automotive sectors). This will continue until 2020, with an increase in world demand of 105%. The steel industry in OECD countries has made significant technological progress over the last 20 years, fostering increased efficiency and resource use, and reducing releases of pollutants. The use of recycled materials in the industry has also been constantly growing (OECD, 2001).

## 2.4 Activities related to secondary production

### 2.4.1 Batteries

NiCd batteries can be classified into four lines of products, according to the market applications: industrial batteries, emergency lighting units (ELU), cordless power tools (CTP) and applications in numerous electrical and electronic equipment (EEE). It is the sector with the highest current and expected future use. Approximately 75% of batteries produced are used for the portable applications such as power tools, cordless appliances, cellular phones and portable computers.

According to their capability for re-use, batteries can be classified as primary and secondary batteries (the latter can be recharged). The NiCd ratio in most batteries is around 3:1, but the amount of cadmium in the battery can vary from grams to tens of kg, depending on the use: domestic appliances, photographic and TV lights, portable computer and hospital equipment, electric vehicles, aircrafts and military and industrial applications. The residues of battery production depend largely on the production process. The various types of NiCd batteries have a very wide range of composition: consumer batteries with an average of 13% and industrial with an average of 8% cadmium. Large batteries can even contain 50% (EUPHEMET, 2000). At present, approximately 3 700 tonnes of industrial NiCd batteries are in the EU market including Norway (TRAR, 2002).

The use of cadmium in portable rechargeable batteries grew strongly during the "cordless revolution" from 1985-1990. Growth continued in the 1990s, but a more moderate growth is expected by the adoption of new battery systems with higher energy capacities for certain applications such as portable computers and cellular phones. Present growth rates for portable NiCd cells range from 5 to 10% a year, while the growth rate for the industrial NiCd cells is 2-4 % a year (OECD, 1994). It can be concluded that at present approximately 13 190 tonnes of portable NiCd batteries are in the EU market including Norway. A positive growth rate for all types of portable secondary batteries is also identified for future years (TRAR, 2002).

The EU market is under a slight growth rate with higher market shares in countries like France, United Kingdom, Italy and Spain, in contrast to Germany where centralised units powered by lead-acid batteries are used (TRAR, 2002).

The evolution of the electric vehicle market within the EU in 1998 was estimated at 90 000 vehicles (OECD, 1994), although it did not exceed 15 000 in 1999 (in EUPHEMET, 2000). A reason for this delay in production is low efficiency of electric vehicles when compared to combustion vehicles. This factor has encouraged research into developing new substitutive energy systems. There seem to be most possibilities for Ni hydride (Ni-MH) and lead-acid. The percentages of batteries used in Sweden, in electric vehicles, for the period 1993-mid 2000, were: 67%, 25%, 2% and 7% for Ni-Cd batteries, lead acid, Ni-MH and unknown, respectively.

Concerning alternatives to NiCd batteries, nickel-hydride (Ni-HM) and rechargeable batteries are now introduced for some field applications (OECD, 1994). The first lithium battery was developed for military applications in the early 1970s. A recent development (since 1992) is the lithium ion secondary battery. This battery does not suffer from the so called "memory effect" as for the overcharged NiCd batteries. They seem to be environmentally friendlier, since they will not have any of the environmental problems associated with cadmium and are safe because the lithium is in the form of lithium ions rather than lithium metal (Noréus, 2000).

Some countries have started programmes to recycle portable cadmium batteries: Switzerland (1990), Belgium (1993), UK and Ireland (1994), the Netherlands (1995), Denmark (1996), Norway (1997), Germany and Sweden (1998) and France (1999). In Spain recycling has been announced but has not yet been implemented. Recent improvements in cadmium recovery are due to environmental concerns and collection programmes related to Council Directive 91/157/EEC on batteries and accumulators. In 1999, the figure for recycling portable batteries was 1 638 tonnes (EUPHEMET, 2000). The collection rate for small batteries is unlikely to exceed 50-60% in the foreseeable future if the prices of cadmium remain at the present levels (see Table 2).

The increase in the market of cordless products, telecommunications and solar equipment, will increase the production and use of cadmium batteries, due to their high efficiency. But it is also expected that environmental restrictions will provoke a substitution of NiCd batteries for other sources of energy which are more environmentally friendly.

### 2.4.2 Solar cells

The possible use of solar energy as a main source of energy for public use is increasing very fast and it is been strongly encouraged by administrations. Due to its very special properties, cadmium is a component of solar cells, mainly as cadmium telluride (CdTe) and to a lesser extent cadmium sulphide (CdS). There is very little waste generated in the film of the cells, but due to encouragement to use alternative sources of energy, it is expected that there will be a huge increase in the production of solar cells. Control of releases and strategies for recycling must therefore be introduced without delay to avoid transforming this clean energy source into one that causes concern from a point of view of pollution. It is expected that the average life of solar cells will be a minimum of 25 years. Thus, there is time to programme the correct management of their production, use and especially recycling.

### 2.4.3 Alloys and electronic compounds

A few special alloys, with deliberate addition of cadmium to obtain specific properties, are produced in very low volumes and could result in limited cadmium releases (OECD, 1994). For example, cadmium is added to copper in small amounts to increase strength without reducing electrical conductivity, to reduce melting temperatures and to improve surface tension characteristics. Uses include electronic switches, gates and sensors, as well as a number of other low-volume but very highly specialised applications: coating telephone cables, trolley wires, tyre-wheels, welding, electrodes, automatic sprinkling systems, steam boilers, fire alarms, high pressure/temperature bearings, starting switches, aircraft relays, light duty circuits breakers, low temperature solder, and jewellery. In devices requiring high safety standards, cadmium is used to ensure the reliability of electrical contacts. These devices consume only very small amounts of cadmium, which is largely recycled.

The EEE market, which has been the largest market segment for the NiCd batteries for the first half of the nineties, is declining. In Europe, in the late 1980s EUPHEMET has identified that 172 tonnes Cd/year was consumed in alloys, with less than 1 tonne/year emissions to air. In 2000, this amount has been estimated 30-40 tonnes Cd/year with small emissions to air of approximately 3-4 kg per tonne.

### 2.4.4 Pigments/colouring agents

Specific properties, such as resistance to high temperatures and durability, make it difficult to substitute cadmium in plastic applications. A wide range of bright red, orange and yellow pigments for plastics, ceramics, glass, enamels and artist's colours are based on the insoluble compound cadmium sulphide (CdS). In some applications of pigments, cadmium can be replaced by zinc. Discharges of cadmium from this use are minimal, substitutes for its use in pigments have been proposed: zinc (for green yellow colours), selenium (for reddish colour) and mercury (red to brown). Due to the characteristic of brilliant red colours and durability, the regulation permits, explicitly, its use in safety systems, i.e. in coloured products and products using cadmium-based stabilisers, in which cadmium is used for safety reasons (Council Directive 91/338/EEC).

### 2.4.5 Stabilisers

Organic cadmium compounds, generally laureates or stearates used in combination with barium sulphate, were utilised in either solid or liquid form to stabilise polyvinyl chloride (PVC). PVC is used in applications such as pipes and gutters, windows and door frames, cable shielding, roofing, swimming pool covers, and numerous other uses where long-term weathering, heat and UV resistance is required to prolong the life of a product (OECD, 94). Council Directive 91/338/EEC forbids the use of cadmium stabilisers for some uses such as in packaging materials, stationery supplies, fitting and furniture.

### 2.4.6 Coatings

Metallic cadmium and cadmium alloy coating are utilised due to a combination of excellent corrosion resistance, particularly in salt solutions, and either a low coefficient of friction, low electrical resistance, or where good brazing characteristics are required. These are minor uses, which can be considered as diffuse sources of cadmium pollution. Losses of cadmium during coating and electroplating processes have been estimated between 1-3%. It is assumed that 20-30% goes to waste disposal or dissipates to the environment during the years of service of the products (EUPHEMET, 2000). Environmental pressures and legislation have promoted a decrease of electroplating, to approximately 300 tonnes Cd/year in 1990. In recent years, cadmium coatings have been increasingly recycled through the re-melting of cadmium-coated scrap steel (OECD, 1994). Plating is expected to produce some 5 tonnes of sludge and less than 1 tonne of liquid containing cadmium. Aluminium, zinc, tin and polymers have been listed as possible substitutes.

## 2.5 Other activities and sources

### 2.5.1 Fossil fuel combustion

Cadmium is a natural constituent of fossil fuels such as coal, oil and peat. The cadmium content of coal varies from 1 µg/g (lignite) to 2 µg/g (bituminous coals) (Hutton, 1982). The cadmium content of crude oil is lower than that of coal, and an average value of 0,05 µg/g has been indicated (Hutton, 1982, OECD, 1994). Substitutes for heating and fuel combustion vehicles are possible and encouraged by administrations.

### 2.5.2 Mineral fertiliser and liming

Application of phosphate fertilisers introduce into soils a portion of the cadmium contained in the original phosphate rock. Igneous phosphates, such as those from South Africa or Russia, are very low in cadmium content; sedimentary phosphates tend to contain more. West African phosphate rocks contain between 45 and 90 ppm cadmium, while those from the Maghreb and the Near East contain 10-70 ppm. Phosphate rocks from the United States contain 5-100 ppm cadmium, depending on the deposit, and those from the Pacific Islands around 70 ppm. (OECD, 1994).

The agricultural application of phosphate fertilisers represents a direct input of cadmium to arable soils. The annual rate of cadmium input to arable land from phosphate fertilisers was estimated by Hutton (1982) at 5 g/ha in EEC countries. This only represents about 1% of the total soil surface burdened by cadmium, but long-term continuous application of phosphate fertilisers has shown to cause increased cadmium concentrations in soil (Williams and David, 1976; Anderson and Hahlin, 1981), which, in turn, can cause increased cadmium levels in crops and fresh water environments. To avoid pollution some countries have stipulated maximum concentrations of Cd allowed in phosphate fertilisers (Table 3).

Contamination of the marine environment due to fertilisers can also occur through manufacturing losses and disposal of the by-product phosphogypsum to the sea. According to estimates for 1978 (Hutton, 1982), EC cadmium discharges during fertiliser manufacturing and cadmium emitted/incorporated in phosphogypsum was 96 tonnes/year. According to this study in the 1990s the main contributors of discharges were France (31 tonnes/year), Spain (24 tonnes/year) and the Netherlands (18-20 tonnes/year). The cadmium inputs of $P_2O_5$ in fertilisers, presented in Table 3 are much higher than the estimated reduction in the EU annual consumption from 4,5 tonnes in 1990 to 3,6 tonnes in 1995 (EUPHEMET, 2000). In 1998, almost 1,87 million tonnes of phosphate rock from Morocco was exported to Spain (EUPHEMET, 2000). The phosphate fertiliser industry plants in the Netherlands have been closed down and ceased production in the year 2000.

**Table 3 Maximum concentrations of Cd (mg Cd) allowed in phosphate fertilisers by some countries**

| Country | Limit[9] (mg Cd/kg $P_2O_5$) | Cd input in soil | | Reference |
|---|---|---|---|---|
| | | Tons | g/ha.a | |
| Belgium | 90 (voluntary) | 5,5 | 3,7 | Pearse, 1995 |
| Denmark | 45 | 2,6 | 0,9 | Provided by Denmark, 2000 |
| France | - | 92 | 3,2 | Laudner et al., 1996[12] |
| Finland | 22 | - | <0,1 | Pearse, 1995 |
| Germany | 60 (voluntary) | 20.4 | 1,7 | Provided by Germany (EFMA, 1995) |
| Ireland | | 9 | 1,8 | Laudner et al., 1996[12] |
| The Netherlands | - | 3 | 4,5 | Molenaar and Lexmond, 1998 |
| Norway | 35 | - | - | - |
| Portugal | 44 | - | 1,4 | MFG, 1996 |
| Spain | - | 30 | 1,5 | Laudner et al., 1996[12] |
| Sweden | - | 1,1 | 0,5-0,8[10] | Pearse, 1995 |
| Switzerland | 115 | 0,5 | 1,2 | Provided by Switzerland, 2001 |
| UK | 115 | 11,3 | 0,9-2,1[11] | Pearse, 1995 |

(-) no data or information available

### 2.5.3 Manure as fertiliser

Heavy metals, especially zinc, are used as a mineral complement in the diet of animals in intensive farming. The assimilation by the animals is not very high and therefore, their presence in excrements has been detected. Cadmium can also be found in manure, in trace quantities, joined with zinc, but intensive farming generates tonnes of residues and therefore a source of metals (Carballo, 1996). Heavy metals are persistent in the environment, and can be accumulated in sediments or soils when applied as fertilisers over the years, especially in sensitive environments. Table 4 shows figures for the input of cadmium to agricultural soils, due to the use of manure as fertiliser.

9 OECD, 1994.
10 MFG, 1996.
11 Alloway et al., 1998.
12 EUPHEMET, 2000.

**Table 4 Cadmium input into agricultural soil through the application of manure/compost (g/ha.year)[13]**

| Country | Manure/compost | Type of manure | Reference |
|---|---|---|---|
| Belgium | 1,75 | Only Pig manure | MFG, 1996 |
| Denmark | 0,49 | Manure/pig slurry | Provided by Denmark, 2000[16] |
| Finland | 0,13 | - | MFG, 1996 |
| Germany | 4,1 | - | Severin, 1999 |
| The Netherlands | 2,1 | - | MFG, 1996 |
| Sweden | 0,05 | - | KEMI, 1998 |
| Switzerland | 1,0 (0,5/0,5) | - | Provided by Switzerland, 2001 |
| UK | 1,7 | Dairy sludge | Alloway et al., 1998 |
| UK | 2,1 | Beef slurry | Alloway et al., 1998 |
| UK | 1,4 | Pig slurry | Alloway et al., 1998 |
| UK | 2,7 | Cattle FYM[14] | Alloway et al., 1998 |
| UK | 2,0 | Pig FYM | Alloway et al., 1998 |
| UK | 6,5 | Manure | Alloway et al., 1998 |
| UK | 2,8 | Broiles litter[15] | Alloway et al., 1998 |

### 2.5.4 Sewage sludge

Bans on disposal at sea may lead to an increasing need for land disposal sites or an increased spreading on agricultural land. OECD (1994) anticipated that volumes of sewage sludge generated will increase as a result of more stringent regulations on water quality and sewage treatment. Cadmium in sewage sludge amounted to approximately 135 tonnes/year, 52 tonnes/year of which were contained in the application of sewage sludge on agricultural land; 9 tonnes/year were accounted for in sludge incineration (1,3 tonnes/year of which were emitted to the atmosphere); some 13 tonnes/year were introduced into building materials and a same amount could reach the marine environment. Council Directive 86/278/EEC establishes maximum cadmium limit levels in soil for sludge applications. Leaching and run-off from contaminated sites can cause mobilisation of metals, especially in acidic conditions. The application of sewage sludge may increase cadmium levels in soil, but these increases tend to be much smaller than those arising from the application of phosphate fertilisers and atmospheric deposition. Sewage sludge applications to agricultural land will cease in Switzerland by 2006. Table 5 gives figures in relation to the input of cadmium due to the use of sewage sludge as fertiliser.

13 Data from ERM, 2000.
14 Farmyard manure.
15 The litter composition is not specified; therefore, it is assumed that as usually, whole poultry wastes are used as fertilisers and soil conditioners egg shells, and any other broiler residue, will be part of the litter composition.
16 Danish Risk Assessment of Pesticides.

**Table 5 Cadmium input to agricultural soil via the application of sewage sludge (g/ha/year)[17]**

| Country | Sewage sludge | Reference |
|---|---|---|
| Belgium | 100 | MFG (1996) |
| Denmark | 1,45 | Provided by Denmark, 2000[18] |
| Finland | 0,02-0,05 | MFG (1996) |
| Germany | up to 50 | Provided by Germany, 2002 |
| The Netherlands | 0,2 | MFG (1996) |
| Sweden | 0,03 | KEMI (1998) |
| Switzerland | 1,0 | Provided by Switzerland |
| UK | 22,3 | Alloway et al., 1998 |

### *2.5.5 Incineration of municipal and industrial wastes*

Incinerator designs are geared towards different waste streams and different end products, and operating temperatures vary with the different designs. The destruction and removal efficiency for properly operated incinerators is 99,99% for most waste. Off-gases (emissions) and combustion residues generally require treatment. Air pollution control systems are employed to remove particulates, and to neutralise and remove acids. Wastes with heavy metals can produce a bottom ash with high concentrations of metals. The ashes may require disposal and/or stabilisation. Some heavy metals, including lead, cadmium, mercury, and arsenic may partially vaporise and leave the combustion unit with the flue gases. This may require gas-cleaning systems for removal of these metals.

Municipal waste may contain cadmium products or materials in which cadmium is present as an impurity. The incineration of these wastes has potential for release of cadmium through stack emissions and landfilling of ashes. A study concerning a modern “energy-from-waste” facility in Canada demonstrated that 99,8 to 99,9 % of cadmium introduced to the incinerator was caught in the boiler and the air pollution control equipment (Chandler and Sawell, 1993, cited in OECD, 1994). Therefore, technology allows an excellent retention of cadmium. General reductions in cadmium emissions have been registered in certain countries (about 17% in the Netherlands) (RAR, 2001). Cadmium emissions due to waste incineration in the EU are about 16 tonnes/year. This figure will be lower for the OSPAR area since Ireland and Portugal only incinerate hospital waste (RAR, 2001). The full implementation of the EU Directive 2000/76/EC on waste incineration should reduce the total estimated emissions of cadmium from the incineration of municipal waste, clinical waste and sewage sludge to 1,1 tonnes/year by 2005. Electronic disposals are not included in these estimates.

There is a general increasing tendency towards incineration. This may negate any reduction due to improving standards. Reliable data about total emissions and emission sources are not available at European level (Schmid et al., 2000). Incineration is one of the major cadmium sources. Emissions are likely to increase due to the disposal and incineration of electric and electronic devices containing cadmium and the higher amount of municipal solid waste that will be incinerated in future.

A survey was carried out by the OECD in 1998 asking 10 European countries about their present and future waste minimisation problems and priorities in key waster streams. This survey identified an increasing concern in relation to Waste from Electric and Electronic Equipment (WEEEs). Only Germany and the United Kingdom identified this subject as a present concern, but it was of concern for the future also for Austria, Finland, France and Norway (OECD, 1998).

17 Data from ERM, 2000.
18 Danish Risk Assessment of Pesticides.

### 2.5.6 Releases from landfills

At present, landfills are the predominant disposal route for wastes, although there are major differences between countries. In UK 75% of municipal waste is landfilled, while the percentage in Sweden is 30%.

Five major components were identified in landfills: newsprint, corrugated containers, plastic film, yard and garden waste and ferrous cans. The OECD (1994) has reported how much of the industrial and household waste water is disposed of according to environmentally sound practices. Major releases of cadmium are due to industrial waste streams and leaching of landfills, and from a variety of operations that involve cadmium or zinc. On the other hand, cadmium is generally not present at significant concentrations in leachates from municipal landfills (Schmid et al., 2000).

Results from laboratory experiments on leaching of cadmium from pigmented plastics have been interpreted as showing that these products would not contribute significantly to cadmium leachate from landfills (Wilson et al., 1982). In general, landfill leachate quality had improved since 1980, probably due to better waste management and landfill practices (AWD technologies, 1993) and an increase in recycling of leacheable products.

It has been estimated that the total cadmium load disposed of in landfills is 1000 tonnes/year in the 12 pre-1994 Member States of the EU, 214 tonnes/year of which arises from landfill of ash.

Although leachate from landfills containing industrial waste could have high concentration of heavy metals, this problem can be solved by appropriate waste treatment prior to discharge. In the case of cadmium, almost complete recovery (99,7%) can be achieved using adequate water treatment.

### 2.5.7 Cadmium in waste streams

The significance of releases during manufacture is dependent on the production processes and the pollution control techniques applied. Releases from these processes may mainly occur to both air and water, but solid manufacturing wastes such as process scrap, sludges and filter cakes may also be generated. Cadmium electroplating may result in discharges and generate wastes such as sludges or filter cakes, but produces negligible atmospheric emissions.

Solid wastes are sent either for recycling or for disposal. Releases associated with the disposal of cadmium related products will depend on the form of product and the techniques employed for disposal. The quantity of cadmium entering the waste stream depends on the lifetime of the product, and their collection rates for recycling cadmium.

### 2.5.8 Traffic and transport

RAR (2001) estimated cadmium releases around 0,6 tonnes/year to air, 0,1 tonnes/year to water and 0,1 tonnes/year to soil. The disposal of products related to traffic, such as discarded tyres, were estimated in 1985 at 6,5 tonnes Cd/year. There is no information about the disposal of these products. The re-use of incineration residues in road construction will result in diffuse losses of cadmium to the environment (RIVM, 1998).

### 2.5.9 Cement production

Cadmium is present as a trace contaminant in raw materials used for cement manufacturing. The cadmium content in these raw materials has been estimated to be around 2,0 ppm. The extent of cadmium emissions to the atmosphere will depend on efficiencies in dust collection. Releases of cadmium to water are unlikely to be significant.

### 2.5.10 Offshore discharges

In relation to offshore pollution, three potential sources have been identified: direct dumping of wastes from land at sea, discharges from ships and from offshore oil and gas installations. Cadmium discharges from ships can be considered as a minor source, in 1990 they were estimated to be <0,1 tonnes/year in the Greater North Sea (Wulffraat et al., 1993).

Table 6 shows information for 1997 and 1998 on the dumping at sea of dredged material containing cadmium.

The offshore oil and gas industry was not considered a relevant source of cadmium. This metal is only present as a natural trace contaminant in barite, which is included in the OSPAR List of Substances/Preparations Used and Discharged Offshore which are Considered to Pose Little or no Risk to the Environment (PLONOR). In the form of barite it is unlikely that cadmium is bioavailable (OSPAR, 2002).

**Table 6 Tonnes of Cd in dredged material dumped at sea within the OSPAR area**

| Country | 1997[19] | 1998[20] |
|---|---|---|
| Belgium | 14,0 | 13,1 |
| Denmark | 0,16 | - |
| France | 10,1 | 8,1 |
| Germany | 0,5 | 1,7 |
| Iceland | - | 0,05 |
| Ireland | 0,5 | 0,1 |
| The Netherlands | 8,6 | 4,8 |
| Norway | 0,01 | 0,25[21] |
| Spain | 4,1 | 1,7 |
| Sweden | - | 0,5 |
| UK | 7,7 | 9 |
| **Total** | **45,67** | **39** |

## 3. QUANTIFICATION OF MAIN SOURCES OF CADMIUM

### 3.1 Introduction

There are three main routes of inputs of contaminants to the maritime area (OSPAR/QSR, 2000): direct, riverine and atmospheric inputs. For the large parts of the maritime area, especially the oceanic parts, the atmospheric transport is the dominant source. Riverine inputs result from run-off from land and discharges into rivers and their tributaries. Fluxes of substances from riverine inputs are heavily dependent on river flow. Estuarine processes can also significantly influence the level of inputs to the marine environment. This makes it difficult to interpret trends and to make regional comparisons. In this case, data on production, environmental measures and monitoring data will be used to better reflect trends.

The following pages contain data on cadmium releases in different OSPAR countries for various years. No data for a given year indicates that no information was available for that country.

19 OSPAR, 2001b.
20 OSPAR, 2001c.
21 Data provided by Norway corresponding to 2000.

## 3.2 Sources of atmospheric cadmium

The largest source of cadmium releases to the atmosphere is the burning of fossil fuels (such as coal or oil) and the incineration of municipal waste. Many industrial sites have tall stacks that bring about a wide dispersion and dilution of emissions of particulates. Steel production can be considered as a significant source, as large quantities of cadmium-plated steel scrap are recycled by industry. Cadmium may also escape into the atmosphere from zinc, lead, or copper smelters. Table 7 shows estimates of atmospheric deposition of cadmium in the Greater North Sea area.

In general, for the Wider Atlantic and the Arctic Waters it is likely that deposition of cadmium is systematically underestimated because the regions were not considered entirely and deposition form sources outside the model area, particularly North America, is not taken into account. Similarly, metal deposition on the Celtic Sea is smaller due to its small surface area. The Irish Sea and Celtic Sea have high concentrations of many pollutants because of long residence times due to slow water circulation patterns (van den Hout et al., 1999).

**Table 7 Atmospheric contributions, based on European emissions, to the total inputs (tonnes/year) of cadmium to the maritime area[22]**

| OSPAR | (Sub)-Regions | 1985 | 1987 | 1990 | 1999 |
|---|---|---|---|---|---|
| Region I | Arctic Waters | - | - | 2,6 | - |
| Region II | Greater North Sea | 262 | | 11-44 | 55 |
| Region Iia | Southern Bight | | 94 | 4,7 | |
| Region Iib | English Channel | | | 1,2 | |
| Region III | The Celtic Seas | - | - | 1,5 -1,8 | - |
| Region IIIa | Irish Sea | | | | |
| Region IV | Bay of Biscay and Iberian coast | - | - | 4,5 | - |
| Region V | Wider Atlantic | - | - | 3,5 | - |

(-) data not available

The atmospheric deposition of cadmium to fresh and marine waters represented a major input of cadmium (Nriagu and Pacyna, 1988). The WHO report on cadmium (1992) which uses a range of different simulation models, estimated the annual input of cadmium to the North Sea as 14 to 430 tonnes/year (van Aalst et al, 1983a and b; Krell and Roexkner, 1988). GESAMP data from 1985 and 1989 is in agreement with these estimates.

Data for atmospheric emissions of cadmium are reported for a number of countries in Table 8.

22 This table and the following tables in chapter 2 are compiled on the basis of data and information in: NSC, 2002; OSPAR, 2001a; OSPAR/QSR 2000; OSPAR, 1998; OSPAR, 1997; GESAMP, 1985; GESAMP, 1989; QSR, 1993; QSR, 1987; Rojas et al., 1993; Nijenhuis et al., 2001; van den Hout et al., 1999; Wulffraat et al., 1993; WMO (1972-1988); OECD, 1994; UNECE/EMEP; Report of the German Inquiry Committee on Human and Environmental Protection (Part: Cadmium, 1993); RIVM, Netherlands' National Environmental Outlook 1993-2015; Swiss Agency for the Environment, Forest and Landscape, Anthropogenic atmospheric emissions in Switzerland, publication No. 256, 1995. Some Contracting Parties submitted specific data for these tables.

**Table 8 Data of atmospheric emissions (tonnes/year) of cadmium per country (UNECE/EMEP)**

| Country | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 9,90-10 | 8,52 | 7,15 | 5,77 | 4,40 | 6,38 | 4,62 | 4,60 | 3,60 | 3,31 |
| Denmark | 1,13 | 1,08 | 1,03 | 0,98 | 0,93 | 0,88-2 | 0,83 | 0,78 | - | 0,71 |
| Finland | 4-6,34 | 3,40 | 2,90 | 2,90 | 2,40 | 1,2-1,70 | 1,48 | 1,06 | 1,25 | 0,56-0,6 |
| France | 15-15,96 | 16,32 | 15,69 | 14,98 | 14,32 | 13,72 | 13,87 | 13,10 | 12,81 | 12,08 |
| Germany | 31,00 | 27,00 | 23,00 | 19,00 | 15,00 | 11,00-32 | - | - | - | - |
| Ireland | 1,62-2 | 1,61 | 1,61 | 1,62 | 1,62 | 1,63 | 1,63 | 1,64 | - | 1,65 |
| Netherlands | 2,38 | 2,33 | 2,33 | 1,84 | 1,68 | 1,51-2 | 1,83 | 1,88 | 1,14 | 1,01 |
| Norway | 1,70 | 1,70 | 1,70 | 1,70 | 1,30 | 1,10-2 | 1,20 | - | - | 1,10 |
| Portugal | 3 | 3,04 | 3,08 | 3,12 | 3,16 | 3,20 | 3,24 | 3,28 | 3,32 | 3,36 |
| Spain | 13,19 | 13,99 | 14,78 | 13,68 | 14,09 | 14,52 | 13,54 | - | - | - |
| Sweden | 2,00 | 1,65 | 1,30 | 1,00 | 0,70 | 0,80-2 | - | - | - | - |
| Switzerland | 4,20 | 3,86 | 3,52 | 3,18 | 2,84 | 2,50-4 | 2,39 | 2,29 | 2,18 | 2,18 |
| U. Kingdom | 25,72 | 25,11 | 25,81 | 25,72 | 24,36 | 15,68-25 | 15,05 | 14,46 | 12,96 | 7,01 |
| **Total** | **118,14** | **109,61** | **103,9** | **95,49** | **86,8** | **74,12** | **71,48** | **63,19** | **66,22** | **58,35** |

Table 9 identifies the various source categories and the corresponding emissions of cadmium in 1990. Table 10 gives a summary of major source categories contributing to the total deposition on the OSPAR regions and sub-regions.

**Table 9 Source categories and total European emissions of cadmium for 1990,** (van den Hout, et al., 1999).

| Categories | Activities included | Tonnes/year | % |
|---|---|---|---|
| 1. Stationary fuel combustion | power plants, commercial, domestic and industrial combustion | 170 | 27 |
| 2. Mobile sources | road transport | 140 | 22 |
| 3. Ferrous industry | primary iron and steel industry | 130 | 20 |
| 4. Non-ferrous industry | | 170 | 27 |
| 5. Other sources | extraction of fossils, solvent use, waste treatment, disposal and agricultural | 20 | 3 |
| **Total** | | **630** | |

**Table 10 Distribution of major sources within the (Sub)-Regions (Nijenhuis et al., 2001)**

| OSPAR | (Sub)-Regions | 1990 |
|---|---|---|
| | | |
| Region I | Arctic Waters | 1 |
| Region II | Greater North Sea | 1,3,4,5 |
| Region IIa | Southern. Bight | 1,3,4,5 |
| Region IIb | English Channel | 1,3,4,5 |
| Region III | The Celtic Seas | 1,2,3,4,5 |
| Region IIIa | Irish Sea | 1,2,3,4,5 |
| Region IV | Biscay Bay and Iberian coast | 1,2,5 |
| Region V | Wider Atlantic | 1,2,3,4 |

The relative contributions within some important source categories per sector (%) are:

- the iron and steel industry (130 tonnes/yr): coke (8 %); sinter (18 %); pig iron (3%), electric arc furnace (44%), open hearth furnace (23%) and basic oxygen furnace (3%);
- for non-ferrous industry (170 tonnes/yr): zinc (70,2%); copper (23,7%), lead (5,4%) and aluminium (0%).

## 3.3 Sources of aquatic cadmium

Table 11 gives estimates for quantities of dredged material and associated contaminant loads of cadmium (tonnes) dumped in the North Sea.

**Table 11 Quantity of cadmium in relation to the origin of the dredged material**

| Origin of dredged material | 1990 | | 1994 | |
|---|---|---|---|---|
| | Quantity dumped (million tonnes) | Cd (tonnes) | Quantity dumped (million tonnes) | Cd (tonnes) |
| Harbour areas | - | | 99,8 | 29,0 |
| Estuaries and navigation channels | - | | 87,8 | 31,3 |
| **Total** | **136,0** | **71** | **187,6** | **60,3** |

Non-ferrous metal mines represented a major source of cadmium release to the aquatic compartment (Nriagu and Pacyna, 1988). Direct discharges also arise from liquid effluents produced by air pollution control (gas scrubbing) together with the site drainage waters to fresh and coastal waters (WHO, 1992). Table 12 shows input data measured over different years.

**Table 12 Direct and riverine inputs of Cd (tonnes/year)**

| OSPAR | (Sub)-Regions | 1972-88 | 1983 | 1987 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Region I | Arctic Waters | | | | 0,2 | 0,6 | 0,3 |
| Region II | Greater North Sea | 50-250[e,g] | 110-430 | | 19-33 | 15-25 | 25-32 |
| Region IIa | Southern Bight | | | 78 | - | - | - |
| Region IIb | English Channel | | | | 2,4 | 1,1 | 0,7 |
| | Kattegat | | | | 0,2 | 0,4 | 0,5 |
| | Skagerrak | | | | 3,1-3,2 | 1,5-1,7 | 5 |
| | Norwegian Sea | | | | 0,7-1,0 | 0,9-1,3 | 0,4-1,0 |
| Region III | The Celtic Seas | | | | 9,4-11,5 | 7,6-9,9 | 9,6-12,3 |
| Region IIIa | Irish Sea | | | | 5,7-6,6 | 4,5-5,5 | 5,6-6,5 |
| Region IV | BB and Ib. coast | | | | 32 | 13-19 | 5,7-9,1 |
| Region IVa | Bay of Biscay | | | | | | |
| Region IVb | Iberian coast | | | | | | |
| Region V | Wider Atlantic | | | | 1,4-6,8 | 1,1-4,3 | 1,4-4,7 |
| | Barents Sea | | | | 0,3 | 0,7 | 0,4 |
| **Total** | | | | | | | |

The following data correspond to emissions and discharges produced by different activities and years, by individual countries:

## 3.4 National data

### *3.4.1 Belgium*

The following tables give figures in relation to the releases of cadmium in Belgium (tonnes/year). According to the data in the progress report to the Fifth International Conference on the Protection of the North Sea (NSC, 2002), reductions of releases of 74% and 93% to the air and water compartment respectively have been achieved between 1985 and 1999.

| Sources | 1985 | 1990 | 1999 |
|---|---|---|---|
| Air emissions (tonnes) | | | |
| • Combustion of coal | >0,2 | 0,1 | - |
| • Combustion of oil | >1,21 | 1,21 | - |
| • Production of lead | 3,5 | 1,95 | - |
| • Production of copper | 0,10 | <0,10 | - |
| • Cadmium metal, oxides, salts | >0,5 | 0,36 | - |
| • Production of iron and steel | >2,7 | 2,7 | - |
| • Production of cement | >0,48 | 0,48 | - |
| • Incineration of household waste | >1,7 | 1,7 | - |
| • Transport and infrastructure | - | - | 0,63 |
| • Small and medium enterprises | - | - | 3,1 |
| • Waste/disposal | - | - | 0,054 |
| **Total (tonnes)** | **>10,4-14,8** | **>8,6-10** | **3,87** |

| Sources | 1985 | 1990 | 1995 | 1997 | 1998 | 2000 |
|---|---|---|---|---|---|---|
| Water discharges (tonnes) | | | | | | |
| • Production of lead | <0,15 | <0,1 | | | | |
| • Production of copper | 0,090 | <0,090 | | | | |
| • Cadmium metal, oxides, salts | 1,64 | <1,81 | | | | |
| • Production of iron and steel | >3,5 | 3,5 | | | | |
| • Production of phosphates | >14,2 | >1,75 | | | | |
| • Cadmium processing | 0,068 | >0,068 | | | | |
| • Household waste | 0,5 | 0,5 | | | | |
| Riverine inputs (tonnes) | - | 3,7-4,9 | 2,6-5,1 | 0,1-5,2 | 2,1-2,8 | |
| **Total (tonnes)** | **>20,1** | **>7,8** | | | | **0,89** |

| Sources | 1985 | 1990 |
|---|---|---|
| Solid wastes and disposed products (tonnes) | | |
| • Combustion of coal | >3,6 | 3,6 |
| • Production of lead | 19,7 | 10,7 |
| • Production of copper | 0,29 | <0,29 |
| • Cadmium metal, oxides, salts | 69,0 | 77,0 |
| • Production of iron and steel | >25,4 | 25,4 |
| • Production of cement | >9,8 | 9,8 |
| • Production of phosphates | >9,0 | 9,0 |
| • Fertilisers containing phosphates | 6,2 | <6,2 |
| • Fertilisers without phosphates | 1,0 | 1,0 |
| • Fodder containing phosphates | >2,0 | 2,0 |
| • Household waste and handling | 40,4 | 40,4 |
| **Total (tonnes)** | **>186** | **>185** |

### 3.4.2 Denmark

The following table gives data on the releases of cadmium to the environment in Denmark (tonnes/year) (Jensen and Markussen, 1993). According to the data in the progress report (NSC, 2002), from 1985 to 1999 reductions of 90,9% and 63,2% regarding emission to air and discharges to water respectively have been achieved.

| Sources | 1980 | 1985 | 1990 | 1995 | 1996 | 1999 |
|---|---|---|---|---|---|---|
| Air emissions (tonnes) | 5,0 | 7,8 | 3,1 | 2,0 | 0,3 | 0,713 |
| Water discharges (tonnes) | 5,7 | 0,965 | - | - | 0,9-2 | 0,355 |
| Direct discharges to the OSPAR area | | | | | | |
| Kattegat | | | | 0,085 | | |
| Riverine inputs | | | 0,48 | | 0,0001 | 5,3[24] |
| Releases to the soil (tonnes) | 8,4 | | 5 | | 2,2-3,5 | 30,6 |
| Waste deposits (tonnes) | 32,3 | | | | 12-25[23] | 5,8 |
| Reuse (tonnes) | - | | | | | |
| **Total (tonnes)** | **51,4** | | | | | **42,7** |

(-) no data;

In 1996, air emissions were mainly derived from incineration of waste and flaring of oil products, whereas water discharges were especially derived from waste water and storm-water from municipal waste water, and from sacrificial anodes. Releases to the soil were derived mainly from the use of fertiliser and manure as well as lime from farming. When losses are compared to the figures for 1990 air emissions have been reduced considerably, mainly due to the improvement of incineration plants and the reduction of iron and steel production. However, water discharges have increased considerably mainly due to increased losses from sacrificial anodes. The legislation concerning the maximum content of cadmium in fertiliser has been effective in decreasing losses via this route. The quantity via deposition has reduced. The explanation for this is that the quantities from the production of iron and steel, the fragmentation of scrap and the direct deposition have decreased. However, the quantities resulting from the incineration of waste have increased.

Overall total cadmium consumption is stagnant in Denmark. An estimate of the consumption of cadmium, in 1990 and 1996, shows that there is a reduction of cadmium in relation to plastic and in fertilisers but on the other hand, there is a significant increase in the consumption of closed NiCd batteries.

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23 Some of the residue/ash is used for embankment and backfilling of roads, dams and the like.
24 Amount due to fertilisers: 2,6 tonnes.

| Sources | 1990 | 1996 |
|---|---|---|
| Intended applications (tonnes) | 39 | 37-61 |
| • Chemicals/solar cells | 0,1 | 0,3 |
| Cadmium as impurity (tonnes) | 11-12 | 5,4-9,5 |
| • Alloys | 0,32 | 0,6-0,8 |
| • Jewellery | - | <1,8 |
| • Fertilisers | 2,6 | 0,3-1,3 |
| • Lime | 1,1 | 0,9-1,9 |
| • Coal | 1,6 | 1,4 |
| • Oil products | 1,2 | 0,003-1,3 |
| • Cement | 1,2-2,4 | 2 |
| **Total (tonnes)** | **50** | **43-71** |

### 3.4.3 Finland

Cadmium discharges decreased by 43% from 1995 to 1999, being 108 kg in 1999. Between 1980 and 1999, general reductions of 93% and 81% have been achieved in air emissions and water discharges, respectively – see tables below (in tonnes).

A zinc mine, a zinc refinery and a copper refinery were the largest sources of cadmium discharges to water, equal to more than 90% of the total releases. Their total load was about 0,2 tonnes in 1992. Improvements have been observed mainly due to environmental concern, resulting in cuts in the amount of cadmium discharged from the Kokkola Plant. As a result of authorisations the discharges decreased to 0,1 in 1993 and 0,04 tonnes in 1994.

Cadmium emissions to air amounted to approximately 3 to 4 tonnes in 1992. About half of this came from zinc, copper and nickel refining (OECD, 1994).

Cadmium from waste water treatment plants, was estimated at 22 kg in 1995. In 1997, 60% of the atmospheric emissions were originated from fuel combustion. Combustion of black liquor (kraft pulp) and wood were also important sources.

| Sources | 1980 | 1988/89 | 1990 | 1992 | 1995 | 1999 |
|---|---|---|---|---|---|---|
| Air emissions (tonnes) | | | | | | |
| • Combustion of coal and oil | 0,5-1,0 | 0,95 | 0,02 | 0,09 | 0,1 | 0,1 |
| • Production of non-ferrous metals | 6,0 | 4,85 | 5,1 | 1,8 | 0,1 | 0,2 |
| • Production of iron and steel | 0,25-0,3 | 0,4 | 0,4 | 0,5 | 1,0 | 0,06 |
| • Waste incineration | 0,8 | 0,02 | 0,03 | 0,02 | 0,01 | 0,01 |
| **Total (tonnes)** | **7,6-8,1** | **6,2** | **6,3** | **3-4** | **1,21** | **0,37** |

| Sources | 1980 | 1988 | 1990 | 1995 | 1999 |
|---|---|---|---|---|---|
| Water discharges (tonnes) | | | | | |
| • production of non-ferrous metals | 0,12-0,25 | 0,12 | | | |
| • production of iron and steel | 0,25-0,8 | <0,01 | | | |
| • production of fertilisers | - | <0,01 | | | |
| • cadmium plating | <0,01 | <0,01 | | | |
| • production of sulphuric acid | 0,2 | 0,3 | | | |
| **Total (tonnes)** | **0,57** | **0,52** | **0,16** | **0,19** | **0,108** |

| **Sources** | **1980** | **1988/1989** |
|---|---|---|
| Solid wastes and disposed products (tonnes) | | |
| • combustion of coal and oil[25] | 1,6 | 4,8 |
| • production of non-ferrous metals | - | 135,5[27] |
| • production of iron and steel | - | 3,5 |
| • production of fertilisers[26] | 1,5 | 0,2 |
| • waste incineration | 2,8 | 0,9[28] |
| • cadmium plating | 0,02 | <0,01 |
| • waste to landfills | 3,8-15,1 | 1,5 |
| **Total (tonnes)** | **9,7-21** | **146,4** |

### 3.4.4 France

Nijenhuis et al., (2001) reported 15 tonnes/year as total atmospheric emissions in 1990. For the period 1986 to 1999, France reported data that indicate reductions of 73% to air and 94% to the water compartment (NSC, 2002). However, with regard to air emissions, there is a difference in data reported for 1999: 2,88 tonnes (NSC, 2002) and 12,08 tonnes (UNECE/EMEP (see also Table 7).

| **Sources** | **1986** | **1990** | **1995** | **1996** | **1999** |
|---|---|---|---|---|---|
| Air emissions (tonnes) | 10,65 | 15 | - | - | 2,88-12,8 |
| Water discharges (tonnes) | | | | | |
| • Direct discharges to the OSPAR area | 50,25 | - | - | - | 3,05 |
| • Riverine inputs | | | | | |
| Channel/North Sea | - | 4,7 | 2,7 | 2[29] | - |
| Atlantic | | | | 32[30] | - |
| **Total (tonnes)** | 60,9 | 19,7 | 2,7 | 34 | 5,97-15,85 |

### 3.4.5 Germany

Releases of cadmium to air, water and soil in Germany are presented below (tonnes/year). According to the data in the progress report (NSC, 2002) reductions of 76% and 83% regarding emissions to air and discharges to water have been achieved between 1985 and 1999.

| **Sources** | **1985** | **1990** | **1995** |
|---|---|---|---|
| Air emissions (tonnes) | | | |
| • combustion of coal and oil | 4,8 | 0,7 | 0,5 |
| • iron and steel industry | 7,93 | 4,9 | 2,69 |
| • cement, glass and ceramics manufacturing | 0,87 | 0,95 | 0,19 |
| • non-ferrous metal industry | 5 | 3 | 2 |
| • hazardous and municipal waste incineration | 3,3 | 0,5 | 0,1 |
| **Total (tonnes)** | **21,9** | **10,05** | **5,48** |

25 Cadmium in fly ash of power plants is either used in production of cement (about 50%) or taken to municipal or other landfills.
26 Phosphogypsum from fertiliser production contains cadmium.
27 Jarosite from zinc refining contains 124 tonnes of cadmium.
28 The biggest waste incineration plant was closed in the early 1980s.
29 Loads of cadmium to Seine river only.
30 Loads of cadmium to Loire and Gironde river (incomplete figures).

| Sources | 1985 | 1996 | 1998 | 2000 |
|---|---|---|---|---|
| Water discharges[31] (tonnes) | | | | |
| • agricultural activities | 3,48 | - | - | 2,41 |
| • transport and infrastructure | 8,41 | - | - | 0,24 |
| • Industrial activities | 22,07 | - | - | 0,99 |
| • Waste disposal | 19,38 | - | - | 4,43 |
| • Other diffuse sources | 1,33 | - | - | 1,29 |
| Direct discharges to the North Sea (tonnes) | - | 0,02-0,07 | 0,01-0,06 | - |
| Riverine inputs to the North Sea (tonnes) | - | 5,6 | 6,1-6,3 | - |
| **Total (tonnes)** | **54,7** | | | **9,37** |

Data presented by Nijenhuis et al., (2001) are likely overestimates, according to the trends presented.

| Sources | 1986 | 1991 |
|---|---|---|
| Solid wastes and disposal products to soils[31] (tonnes) | | |
| • Household waste disposed to landfills | 235 | - |
| • Industrial waste disposed to landfills | 226 | - |
| • Utilisation of residues | 158 | - |
| • Fertilisers | - | 20,4 |
| • Sewage sludge | - | 2,4 |
| • Atmospheric deposition | - | 41,5 |
| **Total (tonnes)** | 619 | 64,3 |

### *3.4.6 Ireland*

According to the figures collected no clear reductions have been observed in water discharges (table below), or in atmospheric emissions. However, the low level of releases to both air and water is evident.

| Sources | 1996 | 1997 | 1998 |
|---|---|---|---|
| Water discharges (tonnes) | | | |
| • Direct discharges (tonnes) to | | | |
| Irish Sea | 0,06 | 0,06 | 0,06 |
| Celtic Sea | 0,02 | 0,02 | 0,02 |
| Atlantic | 0,01 | 0,01 | 0,01 |
| • Riverine inputs (tonnes) to | | | |
| Irish Sea | 1,1-1,2 | 0,6-0,7 | 0,9-1,0 |
| Celtic Sea | 1,5-2,3 | 0,9-1,7 | 1,0-2,0 |
| Atlantic | 0,08-0,8 | 0,3-0,9 | 0,6-1,3 |
| **Total (tonnes)** | **4,39** | **3,39** | **4,39** |

| Source | 1990 | 1999 |
|---|---|---|
| Air emissions (tonnes) | 1,62 | 1,65 |

31 Only for German federal states prior to 1990.

### 3.4.7 The Netherlands

The following tables give some figures on releases of cadmium in the Netherlands (tonnes/year) in recent years and future trends. The percentage of reductions of air emissions and water discharges between 1985 and 1999 are 74% and 96% respectively.

| Sources | 1985 | 1990 | 1995 | 1999 |
|---|---|---|---|---|
| Air emissions (tonnes) | | | | |
| • Agricultural activities | - | | | 0,001 |
| • Transport and infrastructure | 0,03 | | | 0,038 |
| • Industrial activities (IPPC) | 3,68 | | | 0,168 |
| • Small and medium enterprises | - | | | 0,832 |
| • Refineries | 1 | 1 | | - |
| • Households | 0,07 | | | 0,061 |
| • Waste/Disposal | 0,67 | 0,6 | | 0,053 |
| **Total (tonnes)** | **4-4,4** | **3** | **2,0** | **1,12** |

| Sources | 1985 | 1990 | 1996 | 1997 | 1999 |
|---|---|---|---|---|---|
| Water discharge (tonnes) | | | | | |
| • Transport and infrastructure | 0,01 | | | | 0,006 |
| • Industrial activities (IPPC) | 16,4 | 4 | | | 0,242 |
| • Small and medium enterprises | 0,006 | - | | | 0,0007 |
| • Consumers | 0,7 | 0,7 | - | - | - |
| • Households | 0,024 | - | 0,2 | 0,2 | 0,006 |
| • Waste/Disposal | 1,041 | - | - | - | 0,476 |
| • Contaminated land and sediments | 0,154 | - | - | - | 0,019 |
| Direct discharges to the North Sea (tonnes) | - | 0,5 | 8,2 | 3,7-4,0 | - |
| Riverine inputs to the North Sea (tonnes) | - | 9,8 | - | - | |
| **Total (tonnes)** | **17,6 -18** | **6** | | | **0,75** |

| Sources | 1985 | 1990 |
|---|---|---|
| Soil (agricultural) (tonnes) | | |
| • animal manure | 4,5 | 4,5 |
| • fertiliser | 7 | 3 |
| **Total (tonnes)** | **12** | **8** |

As a result of the implementation of the cadmium decree, an effective system of collection for NiCd batteries, and recycling of plastic/polymer materials containing cadmium has been developed. A reduction of 90% has been achieved in respect of cadmium waste incineration between 1985 and 1995:

| Sources | 1985 | 1990 | 1995 |
|---|---|---|---|
| Quantity of waste incinerated (millions of tonnes) | 2,45 | 2,7 | 4,3 |
| Cadmium emission in tonnes/year from incineration of waste (tonnes) | 0,662 | 0,609 | 0,060 |

### 3.4.8 Norway

Cadmium emissions and discharges in Norway are presented in the following tables. The percentage of reductions in air emissions and water discharges between 1985 and 1999 have been reported as 50% and 96% respectively.

| Source | 1985 | 1999 |
|---|---|---|
| To air (tonnes) | | |
| • Emissions from smelters, incinerators, etc | 0,09 | 0,041 |
| • Agricultural activities | 0,038 | 0,02 |
| • Transport and infrastructure | 0,087 | 0,092 |
| • Households | 0,12 | 0,14 |
| • Industrial activities | 1,68 | 0,70 |
| **Total** | **2,02** | **1,0** |

| Source | 1985 | 1990 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| To water (tonnes) | | | | | | | |
| • Transport and infrastructure | 0,2 | | | | | | 0,1 |
| • Industrial activities | 39,2 | | | | | | 1,0 |
| • Waste and disposal | 0,53 | | | | | | 0,17 |
| • From contaminated land and sediments | 0,9 | | | | | | 0,2 |
| **Total (tonnes)** | **40,8** | | | | | | **1,5** |
| To different maritime areas (tonnes) | | | | | | | |
| Direct discharges to: | | | | | | | |
| Skagerrak | | | | 0,1 | 0,1 | 0,1 | |
| North Sea | | | | 1,0 | 1,0 | 1,0 | |
| Norwegian Sea | | | | 0,1 | 0,1 | 0,1 | |
| Barents Sea | | 1,09 | 1,09 | 0,0 | 0,0 | 0,001 | |
| Riverine inputs to: | | | | | | | |
| Skagerrak | | | | 3,0-3,1 | 1,4-1,6 | 4,8 | |
| North Sea | | | | 0,5-0,7 | 0,9-1,1 | 0,7-0,9 | |
| Norwegian Sea | | | | 0,6-0,9 | 0,8-1,2 | 0,3-0,9 | |
| Barents Sea | | 3,2-3,4 | 4,9-5,0 | 0,2-0,3 | 0,6-0,7 | 0,3-0,4 | |

About 100 000 tonnes of sewage sludge (dry weight) per year are disposed of in Norway, over 50% according to modern landfill techniques (agriculture and green areas). The rest is deposited in landfill.

### *3.4.9 Portugal*

Nijenhuis et al., (2001) reported an estimate of 3 tonnes/year atmospheric emissions of cadmium in 1990, which is in agreement with the figure reported in 1990 by the UNECE/EMEP. In 1999, an emission of 3,36 tonnes was reported, thus indicating a slight increase in atmospheric emissions.

| Sources | 1990 | 1999 |
|---|---|---|
| Air emissions (tonnes) | 3 | 3,36 |

Information on riverine inputs is only available for 1997 and 1998, which is not sufficient to give a clear picture of the global trend. The input load in absolute terms is of the order 1 tonne/year. However, the low level of releases to both air and water is evident.

| Sources | 1997 | 1998 |
|---|---|---|
| Water discharge (tonnes) | | |
| Direct discharges to the Atlantic O. | - | - |
| Riverine inputs to the Atlantic O. | 1,3-1,4 | 0,5-0,7 |

### *3.4.10 Spain*

Nijenhuis et al., (2001) estimated 37 tonnes/year as total atmospheric emissions in 1990. It is likely that this figure is overestimated. Cadmium emissions, reported by a UBA-inventory in 1997, were lower for other estimates, but these did not reflect a clear trend in decreasing emissions. The data from UNECE/EMEP, corresponding to 1990 and 1996, indicate atmospheric emissions of the order of 13 tonnes. These figures imply an increase of 2% in atmospheric emissions. Evidently, no reduction is reflected within this 6 year period. The high amount reported is also of concern.

| **Sources** | **1990** | **1996** |
|---|---|---|
| Air emissions (tonnes) | 13,19 | 13,54 |

Riverine inputs to the Atlantic for 1997 and 1998 are given below. The data suggests a reduction of 53% in discharges to water, but a two-year period is not a long enough to give a clear picture of the global trend.

| **Sources** | **1997[a]** | **1998[a]** |
|---|---|---|
| Water discharge (tonnes) | | |
| Direct discharges to the Atlantic | - | - |
| Riverine inputs to the Atlantic | 11-18 | 5,2-8,4 |

### *3.4.11 Sweden*

Cadmium emissions from point sources have been reduced considerably, from about 50 tonnes per year in the early 1970s to less than 5 tonnes per year at present. The data given below indicate that between 1985 and 1999 releases to air and to water were reduced by some 80% and 70% respectively.

**Emission of cadmium from Sweden (tonnes)**

| **Sources** | **1977-78** | **1985** | **1990** | **1995** | **1999** |
|---|---|---|---|---|---|
| Air emissions (tonnes) | | | | | |
| Industrial activities: | | 4,5 | | | 0,8 |
| • Ore-based steel works | | | 0,1 | | |
| • Scrap-based steel works | | | 0,1 | | |
| • Primary metal works | | | 1,3 | | |
| • Secondary metal works | | | 0,1 | | |
| • Wastes from mines | | | 0,1 | | |
| • Combustion of oil | | | 0,3 | | |
| Waste disposal | | 0,4 | | | |
| **Total (tonnes)** | **12** | **4,9-5** | **2** | **1,4-2** | **0,8** |

| Source | 1978 | 1985 | 1990 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| Water discharges (tonnes) | | | | | | | |
| Industrial activities | | 2,5 | | | | | 0,608 |
| • Ore-based steel works | | | 0,1 | | | | |
| • Secondary metal works | | | 0,1 | | | | |
| • Engineering industry | | | 0,1 | | | | |
| • Mines | | | 1,0 | | | | |
| • Combustion of wood and peat | | | 0,2 | | | | |
| • Municipal sewage treatment | | | 0,6 | | | | |
| Wastes/Disposal (tonnes) | | 0,2 | | | | | 0,137 |
| To different marine areas | | | | | | | |
| Direct discharges to | | | | | | | |
| North Sea | | | 0,1-3,7 | | | | |
| Kattegat | | | | 0,02 | 0,09 | 0,05 | |
| Skagerrak | | | | 0,001 | 0,001 | 0,001 | |
| Riverine inputs to | | | | | | | |
| North Sea | | | <0,57 | | | | |
| Kattegat | | | | 0,2 | 0,3 | 0,5 | |
| Skagerrak | | | | 0,04 | 0,07 | 0,06 | |
| **Total (tonnes)** | **4** | **2,7** | **2,1** | | | | **0,74** |

The cadmium input to agricultural soils was about 4 tonnes/year in 1994 (OECD, 1994). About 55% of this amount came from atmospheric deposition and 40% from fertilisers. Although there was a reduction of the inputs of fertilisers in the early 1970s, the current input of cadmium still leads to the accumulation of cadmium in soil. To reach a balance between cadmium input and output, a substantial decrease of about 90% in current input would be required.

### *3.4.12 Switzerland*

The contribution from industry and trade is the most important, followed by releases from households. Emissions from traffic are negligible. Reductions in cadmium releases to air and water between 1985 and 1999 have been registered as 52,3 and 72,0% respectively.

**Air emissions from Switzerland**

| Sources | 1984 | 1985 | 1990 | 1995 | 1999 |
|---|---|---|---|---|---|
| Air emissions (tonnes) | | | | | |
| • Agricultural activities | | 0,022 | | | 0,001 |
| • Transport and infrastructure | | 0,062 | | | 0,082 |
| • Households | 0,35 | 0,211 | 0,34 | 0,34 | 0,189 |
| • Trade, industry, agriculture | 4,3 | 4,450 | 2,6 | 1,6 | 1,990 |
| **Total (tonnes)** | **4,7** | **4,745** | **2,9** | **1,9** | **2,262** |

In 1995, emissions to air in Switzerland were approximately 50% lower than in 1985. The contribution to this reduction from industry is the most important, followed by releases from households.

Discharges of cadmium to the river Rhine (catchment area downstream from the Bodensee), with effluents of sewage water treatment plants, have been estimated at 450 kg in 1985 and <275 kg in 1996. In 1996 discharges from diffuse sources contributed a further 790 kg to the total discharges of 1065 kg. Drainage of agricultural land is considered to be the most important diffuse source.

In Switzerland cadmium is emitted to the atmosphere from the metal processing industry, by waste incineration plants, by burning coal, and during the processing of pigments, stabilisers, accumulators or alloys.

**Global emissions of cadmium from Switzerland**

| **Sources (tonnes)** | **1985** | **1990** | **1995** | **2000 (estimated)** |
|---|---|---|---|---|
| Traffic | 0,06 | 0,07 | 0,08 | 0,08 |
| Industry (steel works, non-ferrous metal industry, cement, glass and ceramic manufacturing, waste incineration, combustion in industry) | 4,5 | 4,0 | 2,2 | 2,0 |
| Agriculture/Forestry | 0,02 | 0,001 | 0,001 | 0,001 |
| Households | 0,2 | 0,2 | 0,2 | 0,2 |
| **Total (tonnes)** | **4,7** | **4,2** | **2,5** | **2,3** |

### 3.4.13 United Kingdom

Reductions in emissions to air and inputs to marine waters, between 1985 to 1999 have been reported as 70,0% and 75% respectively (NSC, 2002).

Nijenhuis et al., (2001) reported 25 tonnes/year as total atmospheric emissions in 1995 for the United Kingdom. Atmospheric emissions reported by UNECE/EMEP to 1990 and 1999 were 25,72 and 7,01 tonnes, respectively.

**Inputs and Cadmium (tonnes/year)**

| **Year** | **Upper Estimate** |
|---|---|
| 1985 | 79,9 |
| 1986 | - |
| 1987 | - |
| 1988 | 65,9 |
| 1989 | - |
| 1990 | 63,6 |
| 1991 | 63,4 |
| 1992 | 45,3 |
| 1993 | 39,7 |
| 1994 | 36,7 |
| 1995 | 30,7 |
| 1996 | 26,6 |
| 1997 | 19,6 |
| 1998 | 22,5 |
| 1999 | 22,8 |

(-) no data available

# 4. MONITORING DATA OF CONCENTRATIONS IN THE MARINE ENVIRONMENT

## 4.1 Introduction

The presence of detectable concentrations of metals in the environment does not necessarily indicate the existence of pollution. Human activities have effectively increased the rate of natural weathering and consequently the rate at which metals are introduced into the environment. The aim of this chapter is to obtain comparative data on cadmium concentrations for locations in different years to reflect the environmental evolution of this compound in relation to the effort of reducing discharges and emissions.

Weathering and erosion result in the transport by rivers of large quantities of cadmium into oceans, which is a major flux of the global cadmium cycle. Cadmium levels of up to 5 mg/kg have been reported in sediments from river and lakes, and from 0,03 to 1 mg/kg in marine sediments (Korte, 1983). The average cadmium content of seawater is about 5-20 ng/l in open seas. Concentrations measured in European rivers roughly varies from 10 (Laane, 1992) to 100 ng/l (Jensen and Bro-Rasmunsen, 1992).

In 1997 OSPAR adopted Ecotoxicological Assessment Criteria (EACs) for trace metals and a number of persistent organic pollutants (OSPAR, 1997). These values can be used to identify potential areas of concern for a range of substances, but they should not rigidly be used as standards. The EACs for cadmium are 0,01- 0,1 µg/l for water and 0,1-1 mg/kg dw for sediment. The EAC for sediment was established on a provisional basis.

## 4.2 Concentrations in seawater

For oceanic and offshore areas concentrations are comparable to the Background/Reference Concentrations (BRCs), indicating that widespread contamination is not a general problem. Close to known point sources however the BRCs are sometimes exceeded, indicating localised contamination. Typical difficulties in applying BRCs have been recognised. For example, given that riverine concentrations of metals generally exceed those in seawater, it is almost inevitable that BRCs based on offshore concentrations will be exceeded in estuaries. Additionally, the estuarine geochemistry of metals must also be taken into account. For example, the resuspension of cadmium adhered to particulates during estuarine mixing can generally lead to high concentrations of cadmium in the water column of estuaries.

## 4.3 Concentrations in sediments

When interpreting trace metals in sediment data the difficulty is to establish the extent to which the concentrations observed are determined by geological sources and/or anthropogenic inputs. Trace metals associate preferentially with fine-grained material in sediment. In general, metal concentrations in sediments from estuaries tend to be higher than in those from coastal areas. In the Greater North Sea (QSR Region II), cadmium levels in sediments from the Dutch coastal zone have significantly decreased in those areas where concentrations had previously been the highest. In the Scheldt estuary the maximum concentrations decreased by a factor three between 1990 and 1995. Table 13 shows concentrations of cadmium in sediments from different OSPAR areas.

## 4.4 Concentrations in biota

### *4.4.1 Introduction*

Biota, which accumulates trace contaminants, can be used to assess spatial and temporal variations in the bioavailable concentrations of contaminants in estuarine and coastal waters. Such organisms are generally referred to as biomonitors. Data is given in Table 14. Bioaccumulation data collected and compared within different periods can illustrate changes in tissue concentrations related to reductions or increases in inputs.

In relation to the concentrations of cadmium in biota there are some points which should be taken into account when comparing data from different environmental compartments (Eisler, 1985):

- marine organisms generally contain higher cadmium residues than their freshwater and terrestrial counterparts;
- cadmium tends to concentrate in the viscera of vertebrates, especially the liver and the kidney;
- cadmium concentrations are generally higher in older organisms;
- higher cadmium residues in biota are generally associated with industrial and urban sources, although this does not apply to sea birds and sea mammals;
- the species analysed, season of collection, ambient cadmium levels and the gender of the organisms probably all affect the residue levels.

In the marine environment, where cadmium is mainly present as chloride complexes, marine fish has been shown as the main cadmium source in food (Dallinger et al., 1987).

Bioconcentration of cadmium sulphate, nitrate and chloride has been studied in a wide variety of aquatic organisms and can be quite high in some species, low in others. For example, rainbow trout have a bioconcentration factor (BCF) of 33 while a BCF of 2 213 was measured in the mosquito fish. Similarly, different species of clams have BCFs ranging from 160 to 3 770.

### 4.4.2 Molluscs

Oysters accumulate about twice as much cadmium in summer as in winter due to an increased flow of water through the animal at higher temperatures (Zaroogian and Cheer, 1979). Uptake of cadmium increased with temperatures up to about 16ºC and decreased as the concentration of cadmium in the water increased, and was also dependent on the food rate (Douben, 1989)

The highest concentrations of cadmium in mussels tend to occur in the vicinity of specific industrial sources. Ratios of observed cadmium to BRCs are high in Norwegian fjords where smelters are located (Sørfjord).

Some of the reported decreases of contaminant concentrations in biota can be linked to reductions of specific discharges. Examples include a 50% reduction in cadmium concentrations in mussels from the Seine Estuary following the prohibiting of phosphogypsum discharges in 1992.

For the period up to 1996, trend analysis of metal concentrations in mussels has revealed significant decreases in cadmium concentrations in mussels in the following locations:

- Westerschelde and Eems-Dollard (the Netherlands);
- Sørfjord and Hardangerfjord (Norway);
- Forth Estuary (Scotland) for the period 1981-1999 (Dobson, 2000); and,
- along the French coast.

In a recent study covering the south coast of Portugal (Machado et al., 1999), the Arader River, the Guadiana Estuary and the Formosa ria lagoon have been identified as the sample points that presented the highest concentrations of cadmium in mussels, ranging from 1,3 to 3,1 mg/kg dw. The data reveal a significant increase of metal concentrations in zones directly affected by urban areas and industrial effluents. Cadmium concentrations in mussels were higher than those found by Vale et al., (1985) for the same area 10 years ago. The population, which is concentrated in the coastal zone, increases more than 10-fold over the summer, which aggravates the problem due to inadequacies in sewage treatment facilities. Waste water effluents have been identified as one of the most important sources of pollution affecting the southern coastal waters of the Iberian Peninsula.

### 4.4.3 Fish

The geographical patterns of metal concentrations in fish continue to reflect historical and current sources of contamination.

Data on metals in fish indicate significant downward trends of cadmium concentrations in flounder liver (*Platichthys flesus*) in the Westerschelde and the inner Sørfjord, and in cod liver at the Swedish site Fladen.

### 4.4.4 Sea birds

Cadmium has been found in a wide variety of birds. Particularly high levels have been reported in pelagic sea birds. Much of the cadmium occurs in the kidney and liver, and relatively little is transferred to the eggs. Surprisingly, the concentration of cadmium in sea birds is often higher in areas with little or no contamination from industrial sources (Hutton, 1981; Osborn and Nicholson, 1984).

### 4.4.5 Mammals

Information on metal concentrations in marine mammals is largely limited to Arctic Waters (QSR Region I) and the Celtic Seas (QSR Region III) (OSPAR/QSR, 2000). Cadmium concentrations tend to be higher in kidney than in liver and muscle and levels in blubber are low. An increase in cadmium concentrations with age has been noted for seals, whales and polar bears.

The highest concentrations of cadmium (up to 11 mg/kg) were found in the livers of striped dolphins (*Stenella coeruleoalba*). This is attributed to the dominance of squid, which accumulate cadmium naturally in their diet rather than from direct anthropogenic sources. Off the Scottish coast, samples taken from a variety of stranded marine mammal species (over a period stretching back almost twenty-five years) have been analysed. In all cases, the concentrations found were at the lower end of the ranges for the species concerned.

Muir et al. (1988) sampled white-beaked dolphins (*Lagenorhynchus albirostris*) and pilot whales (*Globicephala malaena*) at the Canadian coast and reported average cadmium concentrations in kidney (dry weight) of 13,6 mg/kg and 108 mg/kg respectively.

## 4.5 Toxicity to marine organisms

Cadmium toxicity data to marine species are given in Table 16.

In 1997 OSPAR adopted Ecotoxicological Assessment Criteria (EACs) for trace metals and a number of persistent organic pollutants (OSPAR, 1997). These values can be used to identify potential areas of concern for a range of substances, but they should not rigidly be used as standards. The EACs for cadmium are 0,01- 0,1 µg/l for water and 0,1-1 mg/kg dw for sediment. The EAC for sediment was established on a provisional basis.

**Table 13 Cadmium concentrations in water and sediments in different locations of the OSPAR area**

| Compartment | characteristics | mean conc. (ng/kg) ng/l | location | country | OSPAR region | year | industrial source | reference |
|---|---|---|---|---|---|---|---|---|
| Water | - | 250 | Norwegian coast | Norway | | 1994 | - | Rygg and Thélin, 1993 |
| | | | | | | | | |
| Freshwater estuary | - | 80-140 | Seine estuary | France | | 1996 | Urban and industrial activity | Blanchard et al., 1999 |
| Sediments | Clay-silt 81-96% | 100 | Barentsburg (Grøfjørd) | Norway | | 1992 | Coal-mining industrialised settlements | Holte et al.,1996 |
| | Clay-silt 81-96% | 120 | Adventfjørd | Norway | | 1992 | | Holte et al.,1996 |

**Table 14 Cadmium concentrations in biota in different locations of the OSPAR area**

| Common name | scientific name | mean Conc. (ng/kg dw) | organ | location | country | OSPAR region | year | industrial source | reference |
|---|---|---|---|---|---|---|---|---|---|
| Mollusc | *Hydrobia ulvae* | 61 ± 5 | | East Frisian Sea | Germany | | 1992 | Not directly influenced by inputs of Rhine, Weser and Elbe | Matting et al., 1997 |
| Polychaete worm | *Lanice. conchilega* | 1420 ± 180 | | East Frisian Sea | Germany | | 1992 | | Matting et al., 1997 |
| Fish | | | | | | | | | |
| flounder | *Platichthys flesus* | 3,4-7,3 | - | Severn estuary | UK | | 1974 | yes | Hardisty et al., 1974 |

**Table 15 Bioconcentration factors of cadmium in laboratory studies**

| Common name | scientific name | size or weight | static or flow[32] | organ[33] | temp (°C) | duration (days) | exposure (µg/l) | BCF[34] | reference |
|---|---|---|---|---|---|---|---|---|---|
| Mussel | *Mytilus edulis* | 32-34 mm | flow | ST | 13 | 166 | 10 | 50802 dw | Riisgard et al., 1987 |
| American oyster | *Crassostrea virginica* | 8,1 g | flow | ST | 22 | 280 | 5 | 2376 ww | Zaroogian and Cheer, 1976 |
| Scallop | *Arquipecten irradians* | 6,8-7,7 g | flow | WB | 16-20 | 21 | 10 | 131 ww<br>3979 aw | Eisler et al., 1972 |
| Bay scallop | *Agropecten irradians* | 0,51-0,73 | flow | ST | 9,5-16 | 42 | 60 | 20400 | Pesch and Stewart, 1980 |
| Crab | *Pandalas montagui* | 2-4 g | - | WB | 10 | 14 | 37 | 152 dw | Ray et al., 1980 |
| Lobster | *Homarus americanus* | 160-169 g | flow | WB | 16-20 | 21 | 10 | 21 ww<br>10 aw | Eisler et al., 1972 |
| Grass shrimp | *Palaemonetes pugio* | 20-33 mm | flow | WB | 9,5-16 | 42 | 60 | 223 | Pesch and Stewart, 1980 |

32 Static: static conditions (water unchanged for duration of test); flow: flow-through conditions (cadmium concentration in water continuously maintained) unless stated otherwise.

33 WB: whole body; WP: whole plant; ST: soft tissues.

34 Chloride salt used unless stated otherwise; bioconcentration factor = concentration in the organism divided by concentration in the medium.
dw: dry weight; ww: wet weight; aw: ash weight.

**Table 16 Toxicity of cadmium to marine or estuarine organisms**

| Common name | scientific name | Size or weight | Static or flow [35] | temp. (ºC) | salinity (º/ₒₒ) | pH | duration (days) | LC50 (mg/l)[36] | reference[37] |
|---|---|---|---|---|---|---|---|---|---|
| AMPHIPODS | | | | | | | | | |
| Marine amphipod | *Marinogammarus obtusatus* | juvenile | stat | 10 | - | - | 4 | 3,5 m | Wright and Frain, 1987 |
| | | | | | | | | | |
| EQUINODERMS | | | | | | | | | |
| Purple sea urchin | *Strongilocentrotus purpuratus* | embryo | stat | 8,2-8,4 | 30 | 7,8-8,1 | 5 | 0,5 (0,4-0,6) m | Dinnel et al., 1989 |
| Green sea urchin | *S. droebachiensis* | embryo | stat | 8,2-8,4 | 30 | 7,8-8,1 | 5 | 1,8 (1,5-2,2) m | Dinnel et al., 1989 |
| | | | | | | | | | |
| M. BIVALVES | | | | | | | | | |
| American oyster | *Crassostrea virginica* | embryo | stat | 20 | 20 | 7,8 | 2 | 3,8 (2,8-4,5) n | Calabrese et al., 1973 |
| Mussel | *Mytilus edulis planulatis* | - | stat | 18,5 | 32,9 | 7,9 | 4 | 1,6 (1,2-2,2) m | Ahsanullah, 1976 |
| Blue mussel | *Mytilus edulis* | 4 g | stat | 20 | - | 8,0 | 4 | 25 n | Eisler, 1971 |
| Soft-shell clam | *Mya arenaria* | 4,6 g | stat | 20 | 20 | 7,8 | 4 | 0,7 n | Eisler and Hennekey, 1977 |
| Atlantic oyster drill | *Urosalpinx cinerea* | 0,6 g | stat | 20 | 25 | 8,0 | 4 | 6,6 n | Eisler, 1971 |
| | | | | | | | | | |
| M. GASTROPODS | | | | | | | | | |
| Eastern mud snail | *Nassarius obsaletus* | 0,56 g | stat | 20 | 20 | 8,0 | 4 | 10,5 n | Eisler, 1971 |
| Snail | *Physa gyrina* | juvenile | stat | 20-22 | - | 6,7 | 4 | 0,41 n | Wier and Wlter, 1976 |
| | | | | | | | | | |

35 Static: static conditions (water unchanged for duration of test); flow: flow-through conditions (cadmium concentration in water continuously maintained) unless stated otherwise.

36 Cadmium added as cadmium chloride; m: measured; n: nominal.

37 All references identified in WHO (1992).

| Common name | scientific name | Size or weight | Static or flow [35] | temp. (ºC) | salinity (º/ₒₒ) | pH | duration (days) | LC50 (mg/l)[36] | reference[37] |
|---|---|---|---|---|---|---|---|---|---|
| POLYCHAETES | | | | | | | | | |
| Ragworm | *Nereis virens* | 7,6 g | stat | 20 | 20 | 7,8 | 4 | 0,7 n | Eisler and Hennekey, 1977 |
| Sandworm | *Neanthes vaali* | 0,37 g | stat | 18,5 | 32,7 | 8,1 | 42 | 6,4 n | Ahsanullah, 1976 |
| | | | | | | | | | |
| CRUSTACEA | | | | | | | | | |
| Copepod | *Euritemora affinis* | nauplius | stat | 22 | 10 | - | 4 | 0,06 (0,001-0,2) n | Roberts et al., 1982 |
| Copepod | *Acatia tonsa* | adult | stat | 22 | 10 | - | 4 | 0,006 (0,001-1,5) n | Roberts et al., 1982 |
| Harpaticoid copepod | *Nitocra spinipes* | adult | stat | 20-22 | 15 | - | 4 | 0,78 (0,4-1,2) - | Bengtsson & Bergstrom, 1987 |
| | | | | | | | | | |
| Shrimp | *Palaemonetes sp.* | - | stat | 18,7 | - | 8,0 | 42 | 1,85 (5,7-7,2) m | Ahsanullah, 1976 |
| Sand shrimp | *Crangon septemspinosa* | 0,25 g | stat | 20 | 20 | 8,0 | 4 | 0,32 n | Eisler, 1971 |
| Hermit crab | *Pagurus longicarpus* | 0,5 g | stat | 20 | 20 | 8,0 | 4 | 1,3 n | Eisler and Hennekey, 1977 |
| Dungeness crab | *Cancer magister* | zoea | stat | 8,5 | 30 | 8,1 | 4 | 0,2 (0,1-0,4) m | Dinnel et al., 1989 |
| | | | | | | | | | |
| FISH | | | | | | | | | |
| Start fish | *Asterias forbesi* | 11,2 g | stat | 20 | 20 | 7,8 | 4 | 0,7 n | Eisler and Hennekey, 1977 |
| Bay scallop | *Argopecten irradians* | 20-30 mm | stat | 20 | 25 | 8,0 | 4 | 1,48 (0,9-2,3) n | Nelson et al., 1976 |

# 5. IDENTIFICATION OF EXISTING ACTIONS AND LEGISLATION

## 5.1 Introduction

This section contains an overview of the existing measures that are currently in force at national and international level for the control of cadmium. It provides a basis for the evaluation of the need for further controls and how these could best be taken forward.

## 5.2 EC legislation

### *5.2.1 Regulations pertaining to use and sources*

- Council Directive 76/769/EEC ($10^{th}$ amendment: 91/338/EEC and Commission Directive 1999/51/EC) relating to the restrictions on the marketing and use of cadmium-plated products or components of such products used in the equipment and machinery for the production of paper and board textiles and in applications of the clothing sector. Finished products, or components of products manufactured from, and preparations coloured with cadmium, may not be placed on the market if their cadmium content (expressed as Cd metal) exceeds 0,01 % by mass of the plastic material. Moreover, if the paints have a high zinc content, their residual concentration of cadmium must be as low as possible and in any event not exceed 0,1 % by mass.
- Council Decision 75/437/EEC concluding the Convention for the prevention of marine pollution from land-based sources.
- Council Decision 85/613/EEC concerning the adoption, on behalf of the Community, of programmes and measures relating to mercury and cadmium discharges under the Convention for the prevention of marine pollution from land-based sources.
- Council Directive 91/157/EEC on batteries and accumulators. The aim of this directive is to approximate the laws of the Member States on the recovery and controlled disposal of those spent batteries and accumulators containing dangerous substances. Appliances into which they are incorporated will be marked in the appropriate manner. The marking must include indications as to the following points: separate collection and, where appropriate recycling, the heavy-metal content. Batteries and accumulators covered by the directive are those containing more than 0,025 % cadmium by weight.
- Council Directive 96/61/EC on integrated prevention and pollution control (IPPC). This directive presents an integrated approach to prevent and reduce pollution from industrial installations. Discharge and emission limit values, parameters or equivalent technical measures should be based on the best available techniques taking into consideration the technical characteristics of the installation concerned, its geographical location and local environmental conditions. Transboundary effects must be taken into account. Among the categories and industrial activities referred to are: production and processing of metals, mineral industry, chemical industry and waste management.

### *5.2.2 Consumer protection*

- Council Directive 88/378/EEC concerning the safety of toys. Taking into account the protection of children's health, bioavailability resulting from the use of toys must not, as an objective, exceed 0,6 mg for cadmium per day.
- Council Directive 84/500/EEC on ceramic articles intended to come into contact with foodstuffs. This directive concerns the possible migration of lead and cadmium from ceramic articles which, in their finished state, are intended to come into contact with foodstuffs The quantities of lead and cadmium transferred from ceramic articles shall not exceed:

- 0,07 mg/dm$^2$ for articles which cannot be filled, and articles which can be filled, the internal depth of which, measured from the lowest point to the horizontal plane passing through the upper rim does not exceed 25 mm;
- 0,3 mg/l for all other articles which can be filled;
- 0,1 mg/l for cooking ware and packaging and storage vessels having a capacity of more than three litres.

- Council Directive 91/338/EEC in relation to stabilisers. The directive prohibits the use of cadmium stabilisers for some uses such as packaging materials, stationary supplies, fitting and furniture, window frames, textile fabrics, stain of cloths, etc. A limit of 0,01% of cadmium is allowed in certain uses under the conditions of this directive.

### 5.2.3 Water

- Council Directive 75/440/EEC and Council Directive 80/778/EEC on standards for surface freshwater destined for the production of drinking water, and for human consumption.
- Council Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community. This directive states that pollution through the discharge of dangerous substances on List I, including cadmium and its compounds, must be eliminated. With regard to these substances on List I, a system of zero-discharges shall be applied to ground water.
- Council Directive 78/659/EEC on the quality of fresh water in order to support fish life. No specific cadmium concentration is given.
- Council Directive 79/923/EEC for shellfish. No specific cadmium concentration is given.
- Council Directive 80/68/EEC for groundwater comprises cadmium and its compounds on List I, for which the introduction into the ground water must be prevented.
- Council Directive 83/513/EEC on the limit values and quality objectives for cadmium discharges from industrial plants. The purpose of the quality objectives must be to eliminate cadmium pollution of the various parts of the aquatic environment which might be affected by cadmium discharges. Minimum requirements necessary to protect aquatic life:
  - the total cadmium concentration in inland surface waters affected by discharges must not exceed 5 µg/l;
  - the concentration of dissolved cadmium in estuary waters affected by discharges must not exceed 5 µg/l;
  - the concentration of dissolved cadmium in territorial waters and in internal coastal waters other than estuary waters affected by discharges must not exceed 2,5 µg/l.

  In addition to the above requirements, cadmium concentrations must be determined by the national monitoring network referred to in Article 5 of the directive and the results compared with the following concentrations:
  - in the case of inland surface waters, a total cadmium concentration of 1 µg/l;
  - in the case of estuary waters, a dissolved cadmium concentration of 1 µg/l;
  - in the case of territorial and internal coastal waters, other than estuary waters, a dissolved cadmium concentration of 0,5 µg/l.
- Council Directive 2000/60/EC (Water Framework Directive). The directive aims at an integrated Community policy on water and cadmium is identified as a priority hazardous substance. The ultimate aim of this directive is to achieve the elimination of priority hazardous substances and contribute to achieving concentrations in the marine environment near background values for naturally occurring substances.

### 5.2.4 Air

- Council Directives 89/369/EEC and 89/429/EEC on waste incineration set emission limit values to air based on BAT for new and existing municipal waste incineration plants. Emission limit values of 0,2 mg/nm$^3$ apply to new municipal waste incineration plants for cadmium as a function of the nominal capacity of the incineration plant.
- Council Directive 94/67/EC on the incineration of hazardous wastes and controlling emissions of heavy metals through prior authorisation. The aim of this directive is to provide for measures and procedures to prevent or, where that is not practicable, to reduce as far as possible negative effects on the environment, in particular the pollution of air, soil, surface and groundwater, and the resulting risks to human health, from the incineration of hazardous waste and, to that end, to set up and maintain appropriate operating conditions and emission limit values for hazardous waste incineration plants within the Community.
- Council Directive 2000/76/EC on the incineration of wastes. The aim of this directive is to prevent, or to limit as far as practicable, negative effects on the environment, in particular pollution by releases to air, soil, surface water and groundwater, and the resulting risks to human health, from the incineration and co-incineration of waste.

### 5.2.5 Soil

- Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil when sewage sludge is used in agriculture.

### 5.2.6 Waste

- Commission Proposal COM (2001) 315 final 2000/0158. "Proposal for a Directive of the European Parliament and of the Council on Waste Electrical and Electronic Equipment (WEEE)". The proposal establishes measures on the prevention of wastes from WEEEs, on their collection, as well as their treatment, recycling and recovery.
- Commission Proposal COM (2001) 316 final 2000/0159. "Proposal for a Directive of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment". The aim of this proposal is to contribute to the harmonisation of national measures on the management and the restriction of the use of certain hazardous substances in waste from electric and electronic equipments (WEEEs).

### 5.2.7 Fertilisers

- Council Directive 76/116/EEC as regards the prohibition of the marketing in Austria, Finland and Sweden of fertilisers containing cadmium at concentrations in excess of those which were fixed nationally at the date of accession (1994 Act of accession), because of their specific situations.

## 5.3 OSPAR measures

The following Decisions and Recommendations, applicable under the OSPAR Convention, are related to cadmium and related industries.

### 5.3.1 Substitution of cadmium

- PARCOM Recommendation 84/2 for Reducing Cadmium Pollution. This Recommendation requires Contracting Parties to respect the scope which exists for the substitution of cadmium by other materials particularly in the fields of electroplating, pigments and stabilisers. The Commission agreed that the risks resulting from the use of cadmium in soldering and alloys were a minor problem.
- PARCOM Recommendation 92/4 on the Reduction of Emissions from the Electroplating Industry. This Recommendation requires the substitution, if technically possible, of hazardous substances; a

maximum concentration in specific waste water streams of 0,2 mg cadmium/l; and to implement technical measures to treat specific in-plant waste water streams that are particularly hazardous (e.g. cadmium, mercury and chlorinated solvents).

### 5.3.2 Batteries and accumulators

- PARCOM Decision 90/2 on Programmes and Measures for Mercury and Cadmium Containing Batteries. This Decision recognises the need for further measures to reduce inputs of mercury and cadmium to Convention waters, and agrees to the recovery and disposal of batteries and accumulators containing more than 0,025% cadmium by weight. To this end, among other measures:
  - batteries and, where appropriate, appliances into which cadmium is incorporated should be labelled with a recovery symbol;
  - the public should be informed about the danger of uncontrolled disposal of spent batteries and the labelling of such batteries;
  - consideration should be given to establishing economic incentives to encourage the recycling of batteries. It is the aim for the collection and recycling of all batteries larger than 500 g and for the collection of at least 80% of smaller batteries.

### 5.3.3 Primary iron and steel industry

- PARCOM Recommendation 91/2 on the Definition of Best Available Technology in the Primary Iron and Steel Industry. This Recommendation covers non-specific emissions, sinter plants, pellet plants, coke plants, blast furnaces and basic oxygen furnaces.
- PARCOM Recommendation 92/2 Concerning Limitation of Pollution from New Primary Iron and Steel Production Installations. This recommendation focuses on sinter plants, coke plants, blast furnaces and basic oxygen furnaces. Waste gases containing dust should be collected and be subjected to dedusting. After dedusting, the gases should not contain more than 50 mg dust/$m^3$. If the dust contains hazardous substances (more than 0,2% cadmium) lower standards should be achieved.
- PARCOM Recommendation 93/1 on the Limitation of Pollution from Existing Primary Iron and Steel Production Installations. This Recommendation focuses on sinter plants, coke plants, blast furnaces. Waste gases containing dust should be collected and be subjected to dedusting. After dedusting, the gases should not contain more than 50 mg dust/$m^3$. If the dust contains hazardous substances (more than 0,2% cadmium) lower standards should be achieved.

### 5.3.4 Secondary iron and steel industry

- PARCOM Recommendation 90/1 on the Definition of the Best Available Technology for Secondary Iron and Steel Plants.
- PARCOM Recommendation 91/3 on Measures to Be Taken and Investigations to Be Carried out in Order to Reduce Pollution from Secondary Iron and Steel Production. This Recommendation reflects the necessity of measures for the reduction of heavy metal contamination in scrap in order to avoid further pollution with *inter alia* cadmium.
- PARCOM Recommendation 92/3 Concerning Limitation of Pollution from New Secondary Steel Production and Polling Mills. In relation to aqueous discharges, waste water flow from pickling and plating should be reduced as far as possible. Discharges of metals from pickling plants should be limited to 0,2 mg cadmium/l as maximum concentration in effluent water (unfiltered samples).

### 5.3.5 Limitation of pollution from other industrial sources

- PARCOM Decision 85/2 on Programmes and Measures on Limit Values and Quality Objectives for Cadmium Discharges.

- PARCOM Recommendation 97/2 on Measures to Be Taken to Limit Emissions of Heavy Metals and Persistent Organic Pollutants Due to Large Combustion Plants (≥50 MWth).
- PARCOM Recommendation 98/1 concerning Best Available Techniques and Best Environmental Practice for the Primary Non-ferrous Metal Industry.
- PARCOM Recommendation 2001/1 for the Management of Produced Water from Offshore Installations.

## 5.4 Other supranational organisations/frameworks

- Ministerial North Sea Conferences. The input of substances into the North Sea between 1985 and 1995 will be reduced by 50%-70%.
- UN-ECE. Cadmium is included in the UN-ECE LRTAP Protocol on Heavy Metals (1998). The objective is to reduce the emissions of those hazardous substances which can be transported through the air over long distances. The Protocol on Heavy Metals signed by the Community within the framework of the UN-ECE Convention on long-range transboundary air pollution sets legally binding limit values, below the levels in 1990 (or an alternative year between 1985 and 1995).
- London Convention (1972) and its Protocol (1996) on the prevention of marine pollution by dumping of wastes and other matter.

# 6. IDENTIFICATION OF MEASURES

## 6.1 Future monitoring and assessment activities

Under the Water Framework Directive 2000/60/EC cadmium and its compounds are designated as priority hazardous substances on the list of priority substances, and therefore extensively included in environmental monitoring programmes. Actually, cadmium is also part of existing coordinated OSPAR monitoring programmes, such as CEMP, CAMP and RID. There is a guidance document for cadmium under the harmonised reporting and quantification procedures for hazardous substances (HARP-HAZ) developed in the framework of the 5th North Sea Ministerial Conference (2002). Taking into account these existing programmes, a new extensive environmental monitoring programme is not recommended.

On the basis of the information collected, there are some gaps in data on emissions, discharges and losses in the southern part of the OSPAR Convention area. Further checks on the adequacy of data should be carried out and monitoring programmes, if necessary, are recommended in the Bay of Biscay and Iberian Coast, including Portugal. In the north of Spain, industrial activities related to mining and heavy industry have ceased in recent years, so an improvement in environmental conditions and decrease of cadmium releases can be expected.

Monitoring studies are recommended in respect of the content of, and migration of cadmium from electrical and electronic equipment in waste streams. In the specific case of landfills, water treatment facilities should be implemented to recover cadmium and to immobilise pollutants.

Households, in relation to solid wastes, and stationary fuel combustion (power plants, commercial, domestic and industrial combustion) have been identified in the 1990s as a very significant source of cadmium. No recent information has been found about this topic, so a monitoring programme should be recommended, since these activities have increased and, therefore, the discharges, emissions and losses from this area.

## 6.2 Identification of possible measures

Following the structure of paragraphs 2.1-2.4 that describe the main anthropogenic sources, this section considers primary production, secondary production and other sources of cadmium, whilst focusing on the possible environmental measures to be implemented in order to achieve the objective of progressive reduction of cadmium levels in the environmental.

### 6.2.1 Primary Production

**Metal extracting activities**
The data contained in this section indicate a significant decrease in emissions of cadmium associated with primary production activities. Measures to capture cadmium have been successful at industrial plants, thus raising the relative importance of cadmium emissions to diffuse sources and activities related to secondary industry. The most important policy options for mitigating the negative environmental effects of the steel industry are: the use of economic instruments (e.g. subsidiary removal, green taxes), the continued technological development, and voluntary agreements with the industry. There are clear general benefits from an environmental point of view of the implementation of European legislation in relation to the measures aiming at the reduction of cadmium emissions from primary industry.

**Toxic tailings spills**
With respect to wastes originating from mining extraction activities, there is another source of heavy metals, and in particular cadmium. These include accidental breakthroughs of the dump barriers used to dispose acid solutions which have been used for the separation and refinement of metals. These aqueous solutions usually also contain a complex mixture of highly toxic waste metals. In recent environmental accidents, such as those that occurred at Doñana National Park (Southern Spain) or in Aitik (Northern Sweden), the lack of environmental measures in relation to these hazardous activities and installations has been demonstrated. Some of these aqueous acid wastes mixed with heavy metals, including cadmium, have produced significant and irreversible environmental damage. In view of the potential dangers for the environment of these mining wastes, legislation in this area needs to be strictly implemented.

This point is specially important because activities of the extraction industries concerned with exploration for, and the exploitation of, minerals in mines and quarries or by means of boreholes, are explicitly excluded from Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances, (known as Post-Seveso II Directive). In order to avoid similar accidents or depositions of hazardous sludges, it is proposed to establish and enforce environmental legislation, in relation to security measures concerning dams containing aqueous acidic-metallic sludges, and to carry out risk assessment studies. This should be coupled with waste audits.

### 6.2.2 Secondary production

The sources of secondary producers have become more significant to some extent because emissions of cadmium from primary producers have been reduced substantially during recent years. There are big differences in emission levels for different countries. A reduction of industrial emissions would therefore be desirable in those countries that have not implemented reduction measures.

Up to now there is limited data for direct inputs of contaminants from municipal and industrial outfalls in coastal waters and from offshore activities and dumping. Information on this point would need to be collected more consistently. The extent to which sewage is treated prior to discharge varies but in most locations improvements schemes are underway and there are indications that in affected areas the concentrations of some contaminants are decreasing. Because of national legislation and improvements in industrial manufacturing processes, the direct input of contaminants to the Convention area has generally decreased. To reinforce this issue, Best Available Techniques (BAT) should be applied universally for abatement control and end-of-pipe treatment of flue gas and waste water. To ensure that adequate standards for discharges and emissions are achieved, there would be benefit in establishing internationally accepted and ecologically based water quality standards as an intermediate tool/step to achieve a decrease in and a reduction of discharges and emissions. In the Risk Assessment Report on Cadmium (RAR, 2001), Predicted No Effect Concentrations are presented for different environmental compartments. These values can be taken into account for this purpose.

**Batteries and accumulators**

New "clean" technologies, have been identified as being of growing concern in respect of the anticipated greater use of batteries and accumulators.

The use of "alternative energies" for different industrial appliances, such as electric cars and solar cells, is not very high at present, but will be high in the near future. On the other hand, thousands of tonnes of cadmium-containing electric appliances will be abandoned by consumers, so the risk of releases of cadmium will be higher than at present. Therefore, there is a need for a good regulatory frame and a greater participation of consumers in the collection programmes, improvement of recycling technologies, and encouragement to recycle and reuse devices. General collection could be facilitated through general contractual obligations to return used batteries.

Substitution of the small nickel-cadmium batteries with nickel-metal-hydride ones has been increasing, especially in portable computers and mobile phones. The great majority of the most commonly used household batteries are already Cd and Hg-free. But many NiCd batteries and accumulators still end up in domestic waste. Retailers who sell portable batteries and accumulators should be obliged to take them back, but pressure must also be put on consumers, requiring them to return portable cadmium batteries for appropriate disposal. From an environmental point of view, lithium batteries also present advantages, especially in relation to their capacity of high rechargeability.

There has not been any significant decrease in the sales of small NiCd batteries over the last 15 years despite the change to alternatives in areas of major use like in mobile telephones and other electric applications. Producers and consumers of electrical portable rechargeable apparatus still prefer NiCd rather than Ni metal hydride. Reasons are the increase in the marketing of battery-powered tools and that alternative batteries are more expensive than NiCd batteries; the prices for these more environmentally friendly batteries are on average 30-40% higher than for nickel-cadmium batteries. From an environmental point of view, an ecological tax system on nickel-cadmium batteries should be considered. This extra tax could be refunded if customers return the old battery when buying a new one. In this way, the less responsible consumers would pay the eco-tax. As far as substitution of cadmium containing batteries is feasible, producers should be encouraged to substitute NiCd batteries with eco-batteries in old electric appliances.

As an intermediate measure that will precede the prohibition of the marketing of small NiCd batteries, except for batteries for special purposes, consideration should be given to obliging manufacturers to recycle returned batteries, or assume responsibility for the disposal of those that cannot be recycled. These requirements for recycling and disposal could be met by manufactures through a joint return system. The aim should be to achieve a reliable programme of recycling between 90% and 99% of cadmium containing materials by 2020.

Up to now, alloys for electronic compounds contain only small amounts of cadmium and they are largely recycled. However, there is a need for more reliable information about the actual recycling of these devices.

**Fertilisers**

There is a general trend to reduce the use of phosphate fertilisers with high cadmium content, but there is a lack of information of the use of phosphate fertilisers in some countries, e.g. Spain. There is also concern in relation to the increasing quantities of manure and urban compost contaminated with cadmium and which is used in agriculture. These practices can result in pollution of surface waters from run off. It is proposed that consideration should be given to risk management measures in relation to the application of manure on agricultural land. In order to estimate appropriate application rates of fertiliser and manure and the specific environmental conditions for such applications, computer decision/support tools for the eco-management of fertilisers and animal manure, can be very useful. It is suggested that the EGPE model (Vega et al., 2002) could be used. It has been developed by the Spanish National Institute for Research on Agriculture and Food (INIA, Department of Environment) as part of Best Environmental Practice to minimise the risk of the main fertiliser constituents, including metals. As an intermediate step, this informatic tool can be used as a risk management tool with the aim to reducing pollution and minimising adverse affects.

**Recycling and Incineration of WEEEs (Wastes from Electric and Electronic Equipments)**
Due to their future disposal, incineration of electric and electronic devices has been identified by some countries as an increasing area of concern. This could lead to increased cadmium emissions. Best Available Techniques in the Separation and recycling of material for incinerating, should be encouraged to avoid emissions.

There are two proposals for Directives of the European Parliament and of the Council on waste from electric and electronic equipment (WEEE). One of these proposals will cover refrigerators, portable computers, printers, cellular phones and small household devices such as toasters, hairdryers, etc. It covers different actions such as: collection, treatment, recovery and disposal, and identifies obligations mainly for producers and public authorities. Collection of devices is the first step of this process, but it will not contribute to solving the problems if consumers are not actively involved in the programme.

**Other sources**
According to the EU project "EuroCad" (EuroCad, 2000) some imported products exceed the concentration of cadmium permitted. The Netherlands and Greece have examined thousands of products. Cadmium was detected in high concentrations in household items: films, toys, computer mice, clothing, footwear (especially slippers and athletic shoes), electric cable insulation, granules, bags, floor and wall covering, water and sewer pipes, packaging materials, medical equipment, beach articles, etc. Also Denmark has identified importation of products with cadmium.

PVC is the synthetic material with the highest concentration of cadmium. Consideration should be given to banning the import or to banning the use of cadmium in PVC products with unacceptable concentrations of cadmium.

# 7. CHOICE FOR ACTION

Cadmium is a metal that is still being used at a significant level in OSPAR Contracting Parties. Even if in the near future reductions in use will not lead to levels close to background concentrations in the marine environment (because of the environmental persistence of cadmium already discharged), every endeavour must be made to move towards the target of the cessation of discharges, emissions and losses of cadmium by the year 2020. The immediate goal should therefore be to reduce these discharges, emissions and losses to the extent possible, together with the proper management of current and future waste flows. Cadmium has been identified as a priority hazardous substance under the EC Water Framework Directive (200/60/EC), which also aims at the cessation of discharges, emissions and losses. This chapter, therefore, is focused on minimising current and, to the extent possible, future sources of cadmium discharges, emission and losses. The actions proposed should complement those which are being developed in the Water Framework Directive.

On the consumption side, cadmium needs to be replaced with other less hazardous substances. Waste disposal is expected to be a major anthropogenic source of cadmium releases to the environment. The most effective means of reducing the cadmium content of waste flows will be to remove it from the goods which will, in due course, become waste. To achieve these goals, measures including, where appropriate, economic instruments and policy measures are proposed, especially for those countries that have not yet done so.

**Primary production**
In relation to primary production a high decrease in emissions has been registered. Anyway, taking into account the goal of continuous minimisation of cadmium discharges and emissions:

- OSPAR, within 2002/2003, will carry out an assessment of both the non-ferrous metal production and processing and the iron and steel secondary industry, in order to assess whether there is a need to review existing, or adopt new, OSPAR measures on hazardous substances for those sectors;
- OSPAR Contracting States should encourage the development of regulations in relation to the management of wastes and toxic tailings spills in order to prevent the pollution from mining activities.

**Substitution of cadmium in batteries and solar cells**
Batteries is the sector with the highest current, and expected future use of cadmium. Approximately 75% of the consumption of cadmium has been identified in this sector. Consequently,

- the European Commission should be invited to revise Council Directive 91/157/EEC and Commission Directive 1999/51/EC in order to ban the use of NiCd-batteries taking into account the fact that NiCd batteries have satisfactory substitutes for most applications. According to the objectives and principles of the Community's environment policy: a) "...the marketing of certain batteries and accumulators should be prohibited, in view of the amount of dangerous substances they contain" (Council Directive 91/157/EEC) and b) "...the Council resolution of 25 January 1988 requires for an overall strategy to combat environmental pollution by cadmium, including measures to restrict the use of cadmium and stimulate development of substitutes" (Commission Directive 1999/51/EC);
- OSPAR Contracting States should consider what measures, including, if appropriate, ecological taxes, should be applied, to make the substitution of cadmium more attractive from an economic perspective (costs of less environmentally harmful batteries are, on average, 30%-40% higher than the cost of NiCd batteries);
- Contracting States should pay particular attention to cadmium containing batteries when designing their recycling campaigns. The aim should be that the recycling programmes should include the goal of recycling over 90% of NiCd collectable batteries by 2020;
- taking into account this goal, Contracting Parties should encourage the direct participation of consumers in recycling campaigns;
- Contracting Parties should consider how they could promote the development of "clean technologies" for batteries and solar cells.

**Substitution of cadmium in other uses**
Approximately 6% of total cadmium production is used for pigments and colouring agents as well as stabilisers and coatings. Many plastic goods appear to breach existing control limits. Therefore,

- OSPAR should consider initiatives to promote substitution; cadmium might be included in these initiatives. Special attention should be paid to avoid the use of cadmium in colorants and its substitution by mercury (which has been used as an alternative in the past);
- OSPAR should invite the European Commission to consider to ban the import and marketing of cadmium containing devices where its presence is not strictly necessary;
- OSPAR should review the actions needed to achieve cessation of discharges, emissions and losses of cadmium by 2020 when the Risk Assessment Reports on Cadmium and on Batteries were available. These reports are being carried out by Belgium within the Technical Meetings on Existing Chemicals under Council Regulation (EEC) 793/93.

**Waste disposal**
In the short term, the use of cadmium in electric and electronic devices may lead to an increased content of cadmium in wastes. Emissions of cadmium from waste incineration installations and other waste disposal installations will need to be strictly controlled. On the other hand, several accidents at primary production suggest that more attention to the proper management of wastes from mining activities is needed. Therefore,

- OSPAR Contracting Parties should ensure that sufficient attention is paid to the level of cadmium emissions authorised under the Integrated Pollution Prevention and Control (IPPC) Directive, or under equivalent national regulation by non EU States;
- OSPAR Contracting States with mining operations in their territories should review the environmental assessments and controls imposed on their wastes, where cadmium is either a direct product or indirect by-product from mining activities. In this sense, this consideration must be strictly taken into account in the assessment of BREF that will be carried out by OSPAR in 2002/2003 by the Hazardous Substances Committee in relation to “tailing and mining waste rock”;
- OSPAR States with mining operations abroad should encourage enterprises abroad to follow an acceptable level of environmental responsibility and that both the Precautionary Principle and the Polluter Pays Principle are applied in their activities;
- OSPAR should invite the European Commission to consider the development of common guidance in relation to the appropriate use of sewage sludge as fertiliser, considering its cadmium concentration and taking into account the different environmental conditions (sensitivity of soils, drift, run-off, etc.).

**Fertilisers**
Fertilisers can have a high cadmium content. General controls on the level of cadmium in such fertilisers are therefore needed.

- OSPAR Contracting States who are EU Member States should seek to ensure the early adoption of common rules on the maximum limit levels of cadmium in phosphates fertilisers and in fertilisers from an animal origin. Other OSPAR Contracting Parties should pursue similar national policies.

**Data and reporting**
OSPAR should review the adequacy of data and reporting relating to the sources and releases of cadmium to the environment and seek to make good any significant deficiencies.

**Co-operation with EC**

- OSPAR should ensure that the information in this background document and the conclusions reached by OSPAR are formally communicated to the European Commission, OSPAR should send a copy of this background document to the European Commission.
- The final Risk Assessment Reports on *Cadmium metal and cadmium (oxide)* and *The targeted report as used on batteries*, are being carried out by Belgium, within the Technical Meetings on Existing Chemicals following Council Regulation (EEC) 793/93. The conclusion of these reports, as well as the Risk Reduction Measures, when proposed, should be examined by OSPAR with a view to assessing whether this will be sufficient for achieving OSPAR’s objectives.

**Co-operation with other bodies**

- OSPAR should ensure that the information in this background document can be considered in the context of other international agreements, which deal with hazardous substances. OSPAR should send copies of this background document to the appropriate bodies dealing with those agreements.
- OSPAR Contracting Parties who are common Parties to OSPAR, and those other agreements should promote that actions of this background document would be taken into account by those other international bodies in a consistent manner.

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# APPENDIX 1: MONITORING STRATEGY FOR CADMIUM

As part of the Joint Assessment and Monitoring Programme (*reference number 2003-22*), OSPAR 2004 adopted an Agreement on monitoring strategies for OSPAR Chemicals for Priority Chemicals (*reference number 2004-15*) to implement the following monitoring for tracking progress towards the objectives of the OSPAR Hazardous Substances Strategy (*reference number 2003-21*) with regard to cadmium. The Monitoring Strategy for cadmium will be updated as and when necessary, and redirected in the light of subsequent experience.

In general, the sources of cadmium are well characterised and understood, and have been described in the EC Water Framework Directive source inventory and the HARP-HAZ guidance document on cadmium. Methodologies for monitoring cadmium are generally well developed.

The Background Document highlights a number of regulations and measures agreed by Contracting Parties both in OSPAR and in other international forums. OSPAR will track progress in the implementation of these measures as a first step towards tracking progress towards the OSPAR objectives.

For air emissions OSPAR will seek to make best use of data reported in other forums. The yearly reporting to EMEP of releases to air in the context of UNECE LRTAP may in principle provide data for cadmium for all significant sources to air. OSPAR will examine and assess these data to determine whether emissions trends are decreasing. In addition, OSPAR will examine the data reported by Contracting Parties to the EPER database on emissions from sources subject to IPPC.

For discharges to water, OSPAR will examine and assess data on sources subject to IPPC activities reported to the EPER database. For other significant sources there is no emission inventory taking place on a regular basis. National data for discharges from non-IPPC sources could be collected at regular intervals. However, not all Contracting Parties have the resources to contribute to such reporting so it should be considered as an additional voluntary monitoring activity. Contracting Parties carrying out such additional monitoring are urged to co-ordinate their activities. The list of indicative sources in the HARP-HAZ Prototype Guidance document for mercury should be taken into account in any initiative to collect this information. As a further voluntary reporting activity Contracting Parties are urged to report any accidental releases of cadmium to the environment e.g. from mining activities or from contaminated land.

Information about production/sales/use of cadmium will be updated on a regular basis, as part of the review of the Background Document. This should take into account *inter alia*:

a. information from IUCLID (ECB);

b. production, use/sales statistics from industry;

c. any national reporting on sales or use figures for products where diffuse releases are relevant e.g. batteries, solar cells and EEEs.

The review of the Background Document should also consider the significance of coastal waste disposal sites, which should in principle be reported on in the national reporting on pressures and impacts in river basin districts under the Water Framework Directive and the requirements in the new EC Landfill Directive.

OSPAR will continue to monitor for cadmium under its existing monitoring programmes (CAMP on atmospheric inputs, RID on riverine inputs, and CEMP on concentrations in marine sediments and biota) as these provide useful information on concentrations in the environment. The requirements for monitoring under the CEMP will be reviewed following the assessment of CEMP data in 2004/05 taking into account *inter alia*

a. the fact that cadmium is a priority hazardous substance under the Water Framework Directive and that, where available, OSPAR will seek to periodically compile results from EC WFD monitoring;

b. consideration of whether the WFD programs are sufficient as regards establishing information on the status of open sea areas and reference sites.

OSPAR reports on the dumping of dredged material will be taken into account in relation with other secondary sources.

The significance of inputs from the offshore sector is not clear, past data on the cadmium content of produced water should be examined to assess its significance.

As a potential additional source of information, OSPAR will keep in mind the EEA's Monitoring and Information Network for Inland Water Resources on the status and quality of Europe's rivers, lakes and groundwater bodies, which is expected to contain information on cadmium, among other different pollutants.

| **CADMIUM MONITORING STRATEGY** | |
|---|---|
| *Implementation of actions and measures* | Examination of progress in the implementation of regulations on marketing and/or use or emission and/or discharge which have been agreed, or are endorsed, by the Background Document |
| *Emissions to air* | Examination and assessment of trends in emissions to air as reported annually by Contracting Parties to the UNECE/EMEP database in the context of the LRTAP Convention and, for IPPC sources, to the European Pollutant Emissions Register (EPER) |
| *Discharges and losses to water* | Examination and assessment of trends in discharges to water from IPPC sources in data reported annually by Contracting Parties to EPER.<br>*Additional voluntary activities*:<br>*Estimation of data on discharges to water from sources not covered by EPER*<br>*Reporting on any accidental releases of cadmium to the environment e.g. from mining activities or contaminated land* |
| *Production/use/sales /figures* | The lead country will update information on production, sales and use of products containing cadmium during review of the Background Document. The next review is planned for 2008/09 |
| *Atmospheric inputs* | Monitoring will continue under the CAMP |
| *Riverine inputs* | Monitoring will continue under the RID study |
| *Inputs from the offshore industry* | Past data on the heavy metals content of produced water discharges will be examined to judge its significance |
| Maritime area: | |
| *Dredged materials* | Continued reporting to OSPAR of the concentrations of cadmium in dredged materials disposed to the maritime area |
| *Concentrations in sediments* | Monitoring will continue under the CEMP<br>Where available, data will be periodically compiled from EC WFD monitoring |
| *Concentrations in water* | Where available, data will be periodically compiled from EC WFD monitoring |
| *Concentrations in biota* | Monitoring will continue under the CEMP |