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Apports Aquatiques et Atmosphériques de Mercure, de Cadmium et de Plomb

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Apports Aquatiques et Atmosphériques de Mercure, de Cadmium et de Plomb

Contributeurs

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Citation

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Contents

Message clé

Les apports des métaux lourds que sont le mercure, le cadmium et le plomb ont diminué depuis 1990. Il est cependant difficile de déterminer quelle part des changements observés s'explique par la réduction des déversements et des émissions pour le cadmium et le mercure car les procédures d'analyse se sont améliorées depuis 1990.

Contexte

OSPAR s'est fixé un objectif stratégique dans le cadre de la Stratégie pour le milieu marin de l'Atlantique du Nord-Est (NEAES) 2030, qui est de prévenir la pollution par les substances dangereuses, en éliminant leurs émissions, rejets et pertes afin d'atteindre des niveaux qui n'entraînent pas d'effets néfastes sur la santé humaine ou le milieu marin, dans le but ultime d'atteindre et de maintenir des concentrations dans le milieu marin qui sont proches des valeurs ambiantes pour les substances dangereuses présentes à l'état naturel et proches de zéro pour les substances dangereuses d'origine humaine. Les métaux lourds sont dangereux car ils peuvent avoir des effets biologiques nocifs affectant le fonctionnement de l'organisme, la croissance, le métabolisme, la reproduction, ou la survie. Trois des métaux lourds les plus toxiques – le mercure, le cadmium, et le plomb – figurent sur la Liste OSPAR des produits chimiques devant faire l'objet de mesures prioritaires du fait de leur toxicité élevée et de leur potentiel de nuisance sur la vie marine.

Le mercure, le cadmium et le plomb proviennent de sources variées et peuvent être issus de processus naturels, industriels ou agricoles. Les engrais peuvent par exemple être source de cadmium (**Figure 1).** Les métaux lourds sont le plus souvent transportés sous forme de, ou fixés à, des particules fines. Ces particules peuvent provenir de sols dénudés ainsi que de la surface de la mer et être transportées par voie aérienne. Les métaux lourds sont donc ensuite transportés dans l'atmosphère. Le mercure, contrairement aux autres métaux lourds, peut également s'évaporer ou être transporté sous forme de gaz. De plus, le mercure et le cadmium peuvent s'accumuler dans la chaîne trophique (**Figure 2**) tandis que le plomb ne s'y accumule pas.

Les apports aquatiques de mercure, de cadmium et de plomb font l'objet d'une surveillance par les pays OSPAR. Les apports atmosphériques sont modélisés par les pays OSPAR (**Figure 3**), en se fondant sur les émissions annuelles notifiées dans le cadre des Directives sur les émissions de l'Union européenne et de la Convention sur la pollution atmosphérique transfrontière à longue distance des Nations Unies.

Figure 1 : Les engrais minéraux sont une source importante de cadmium dans de nombreuses parties de l'Europe

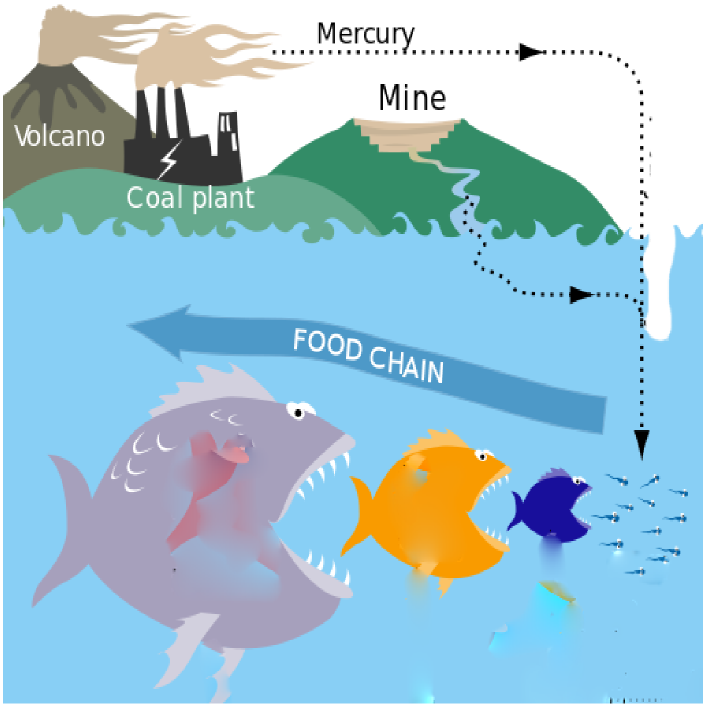


Figure 2 : Le mercure provenant des centrales électriques au charbon et d'autres sources est transporté dans l'atmosphère et l'eau. Le mercure, sous forme de méthylmercure, peut se bioaccumuler par l'intermédiaire des réseaux trophiques marins, atteignant des teneurs élevées dans les prédateurs supérieurs


Figure 3 : Station de surveillance atmosphérique

Contexte (version étendue)

The effects of high levels of heavy metals on humans can include: decreased learning ability (lead, mercury); reduced bone strength (cadmium), and damage to the central nervous system (mercury, lead). This has resulted in restrictions on most uses of heavy metals and strict bans on mercury use. Mercury and cadmium accumulate in the food chain and are considered the most toxic heavy metals.

In the Roman Empire, lead was used for water pipes, as a sweetener in wine (lead-acetate) and as colouring for skin-cream. In modern times, it has been used in car batteries and until 2000 in leaded petrol for motor vehicles, as an engine lubricant and anti-knock agent. This was the main source of lead pollution in air and water during the 1970s until its ban (Larsen *et al.,* 2012). It has also been used as a softener in poly(vinyl chloride) (PVC) piping and insulation. Mercury was used in medicine as an antibacterial agent, and as a liquid anode in electrolysis in the paper industry. It has also been used in dental fillings, in thermometers and other scientific instruments. The Minamata Convention is an international global legally binding instrument banning the use of mercury, which was adopted in 2013 and entered into force on 16 August 2017 with 128 parties ratifying the Convention by 2021. Mercury has uses as a liquid anode in electrolysis in the paper and chlor-alkali industry. Mercury use in chlor-alkali factories is subject to OSPAR Recommendations and EU regulations which have resulted in the adoption of other techniques.

Figure a: Amalgam filling containing mercury. OSPAR works to reduce mercury losses from dentistry and also atmospheric mercury from crematoria https://commons.wikimedia.org/wiki/File:Filling.jpg?uselang=en (Author: Kauzio, Wikimedia Commons) .

Cadmium is used in batteries and electronics, and previously in certain red paints and plastics. It is found in minerals mined for zinc, copper and lead and is a minor constituent of all products of these metals. As it is taken up from soil by plants, it is also concentrated in plants, especially tobacco leaves, sunflower, and linseed.

Both mercury and cadmium are suspected carcinogens, either in some other chemical form or as particles in the lungs.

OSPAR’s Coordinated Environmental Monitoring Programme (CEMP) requires OSPAR countries to monitor heavy metals, including mercury, cadmium, and lead. OSPAR's monitoring work on hazardous substances comprises monitoring and assessment of the sources and pathways of contaminants and their concentrations and effects in the marine environment. In addition to heavy metal inputs, concentrations in biota and sediment are monitored under OSPAR CEMP.

OSPAR has a long history of coordinating and agreeing measures to reduce heavy metal inputs to the North-East Atlantic. As early as 1980, Recommendations to limit heavy metal concentrations in sewage sludge and Decisions about mercury concentrations in organisms were agreed. Further Recommendations to limit mercury pollution came in 1981, 1982, 1989, 1990, 1993 and 2003. Recommendations to limit cadmium emissions were adopted and implemented between 1985 and 2010.

One of the OSPAR North-East Atlantic Strategy objectives 2010-2020 was “a steady reduction in heavy metal inputs” with the ultimate aim that heavy metal inputs should be close to background values (OSPAR Agreement 2010-03). The magnitude of background inputs has yet to be determined in line with the OSPAR NEAES 2030 to

“Prevent pollution by hazardous substances, by eliminating their emissions, discharges and losses, to achieve levels that do not give rise to adverse effects on human health or the marine environment with the ultimate aim of achieving and maintaining concentrations in the marine environment at near background values for naturally occurring hazardous substances and close to zero for human made hazardous substances”.

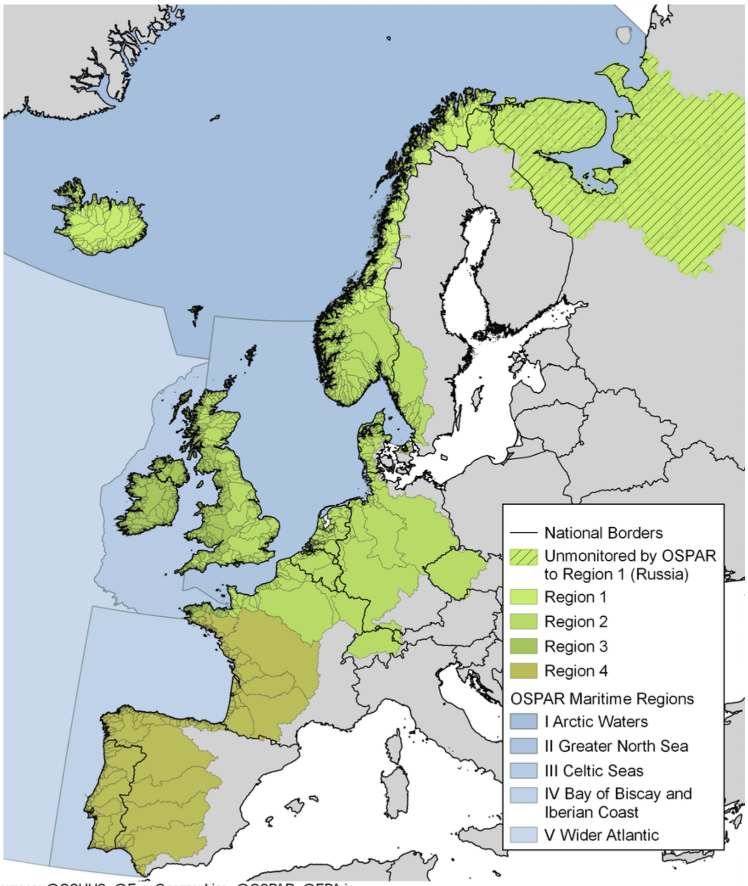


Figure b: Riverine catchment areas supplying mercury, cadmium and lead to the OSPAR convention area

Méthode d’évaluation

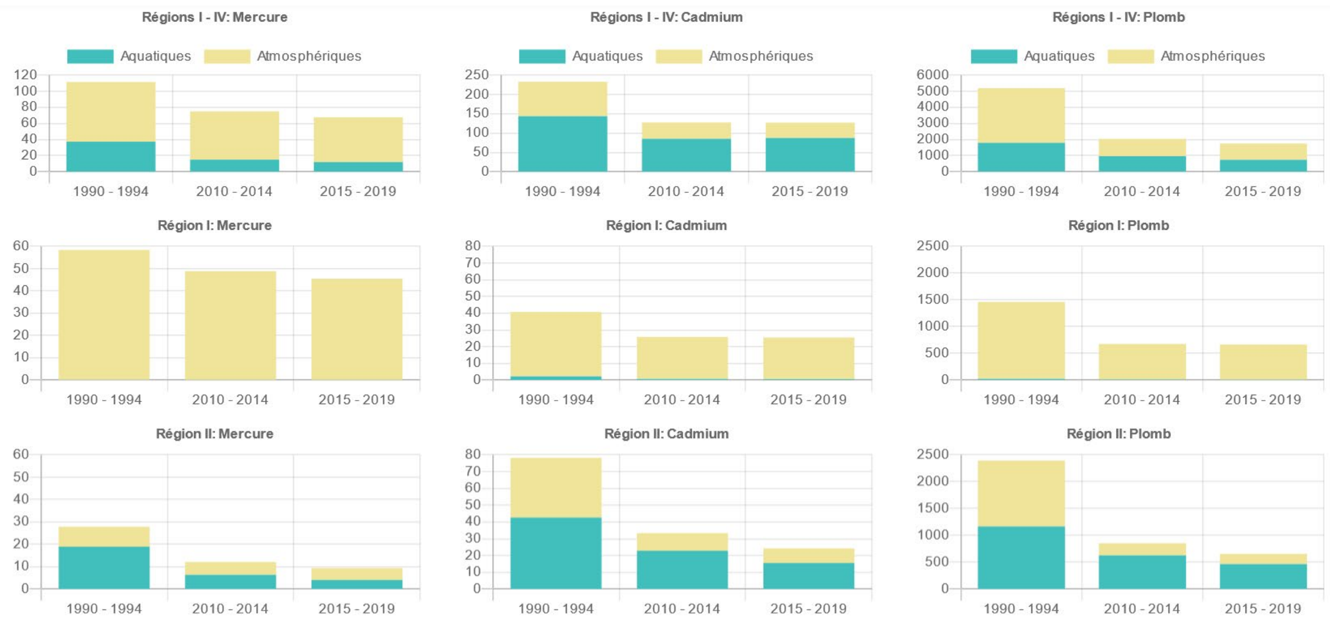
Heavy metals concentrations are measured in OSPAR’s Riverine Inputs and Direct Discharges Monitoring Programme (RID) (OSPAR Agreement 2014-04). These measurements are combined with high frequency freshwater discharge observations to give the total riverine inputs at the river mouth. Inputs are attributed to the country where the water enters the sea, although catchment areas often extend across national borders. These inputs are then supplemented by national reports of waterborne discharges from industry (OSPAR Agreement 2014-04), which European Union Member States also report under the Industrial Emissions Directive and the European Pollutant Release and Transfer Register (E-PRTR) - Environment . Losses from unmonitored areas, between monitored riverine discharge points, are determined by modelling.

Atmospheric input data have been modelled and produced by EMEP–MSC-E (European Monitoring and Evaluation Programme – Meteorological Synthesising Centre East) based on national reporting of emissions to the air under the UNECE Convention on Long-range Transboundary Air Pollution (UNECE, 1983). Emissions data are reported to EMEP, the resulting transport and deposition is then modelled using atmospheric chemistry and meteorological models, together with estimates of ‘background’ heavy metal emissions due to re-suspension from exposed soils and earth or in the case of mercury, emission from the sea surface. Source apportionment allows the relative contributions of OSPAR countries and ‘natural’ sources, as well as sources outside the OSPAR Maritime Area, to be assessed. EMEP model results are validated against EMEP (often including the OSPAR Comprehensive Atmospheric Monitoring Programme, CAMP (OSPAR Agreement 2015-04) observations of heavy metal deposition. More detailed information about EMEP MSC-E modelling is available (Ilyin et al., 2022).

Résultats

Les apports de mercure, de cadmium et de plomb dans la mer du Nord au sens large semblent avoir diminué de moitié depuis le début des années 1990 (**Figure 4).** Cependant, l'amélioration des méthodes d'analyse permettant une meilleure détection des métaux lourds (à des niveaux plus faibles) signifie que s'il y une tendance baissière des apports, cette réduction est sans doute surestimée. Il n'est néanmoins pas possible de déterminer à quel point. Des surestimations se sont produites par le passé car la limite de quantification pour une analyse était plus haute que la concentration réelle de la substance dans l'environnement. De même, certains pays ont changé leurs analyses des métaux, par exemple en passant des métaux totaux aux métaux dissous, depuis la mise en place de Directive cadre sur l'eau de l'Union européenne en 2000. Ce changement a également donné lieu à une réduction apparente des apports. Il est difficile de savoir si des problèmes similaires affectent les données sur les retombées atmosphériques qui dépendent de la qualité des données notifiées sur les émissions, de la précision de la description des processus météorologiques et chimiques, et de la qualité des données de validation.

Les apports aquatiques de mercure ont été réduits de près de 50% entre 1990-1995 et 2010-2014, et ont continué de décroitre ensuite, bien qu'à un rythme moins soutenu. Les apports atmosphériques ont été réduits de près de 30%, ce qui est probablement dû en partie à de meilleures techniques d'analyse. Les apports aquatiques et atmosphériques de cadmium quant à eux ont été réduits des deux-tiers. Les apports aquatiques de plomb ont diminué de plus de 50% tandis que les retombées atmosphériques de plomb représentent moins d'un tiers de celles mesurées en 1990.



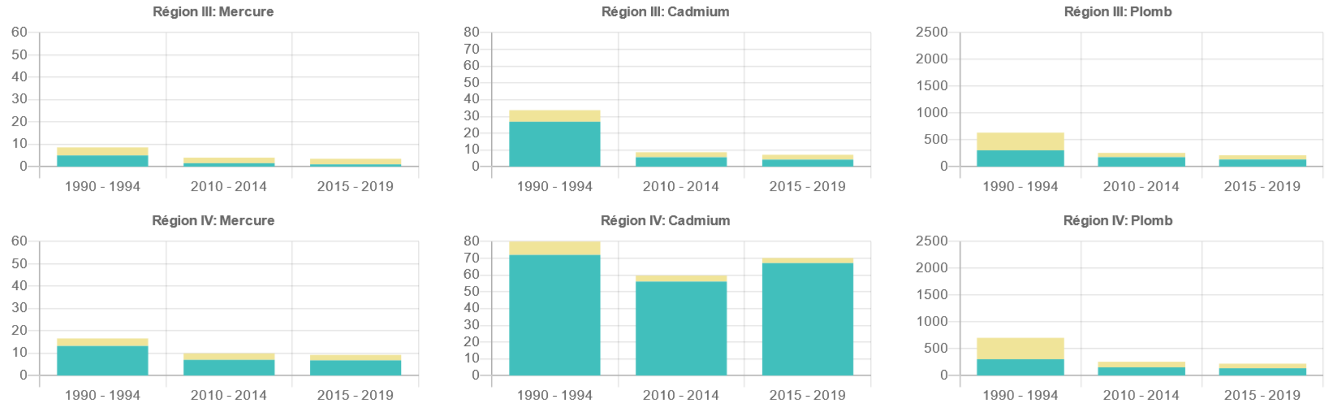


Figure 4 : Apports totaux estimés (aquatiques - bleus et atmosphériques - jaune) de mercure, cadmium et plomb dans les régions OSPAR I -IV pour les périodes 1990 à 1995, 2010 à 2014 et 2015 à 2019. Valeurs exprimées en tonnes.

L'ensemble des pays OSPAR sont parvenus à des réductions substantielles d'apports aquatiques de mercure depuis la période 1990 à 1995, à tel point que les apports aquatiques sont désormais inférieurs aux apports atmosphériques dans la région de la mer du Nord au sens large. Les Pays-Bas et l'Allemagne ont réalisé les réductions d'apport aquatique de plomb les plus importantes : à eux deux ils représentent la moitié du total des réductions observées au niveau des apports aquatiques.

Les apports atmosphériques des trois métaux lourds étudiés ont diminué drastiquement depuis 1990. L'évaluation intermédiaire de 2017 (Intermediate Assessment 2017) a montré que les apports de mercure liés aux émissions des Parties Contractantes étaient bien plus faibles que les apports provenant des pays « non-OSPAR ». Ces apports « non-OSPAR » proviennent de l'extérieur de la zone maritime OSPAR ainsi que des matières remises en suspension issues par exemple des sols dénudés, et des surfaces urbaines, arables, et marines situées aussi bien dans la zone maritime OSPAR qu'à l'extérieur de celle-ci.

La méthodologie utilisée pour cette évaluation inspire une confiance modérée et les données utilisées inspirent une confiance faible.

Résultats (version étendue)

Changes and improvements in analytical methods make it difficult to determine the exact scale of the input reductions for mercury, cadmium, and lead. **Figure c, Figure d, Figure e, Figure f, Figure g**, **Figure h, Figure i, Figure j, Figure k, Figure l, Figure m, Figure n, Figure o, Figure p** and **Figure q** suggest that mercury inputs have decreased by one-third since the early 1990s, cadmium by a half and lead by almost two-thirds. Atmospheric input calculations, based on reported emissions and atmospheric transport and chemistry models have decreased by a similar amount. These results appear to be reflected in the Status and Trend for Heavy Metals (Mercury, Cadmium and Lead) in Fish, Shellfish and Sediment indicator assessment, which describe concentrations in sediment as "decreasing or show no significant change in the majority of areas assessed" and concentrations in mussels and fish as "decreasing or show no significant change in all assessed areas". Despite this, the relevant objective of the OSPAR North-East Atlantic Environment Strategy 2010-2020, that concentrations are at natural background levels, has not yet been met.

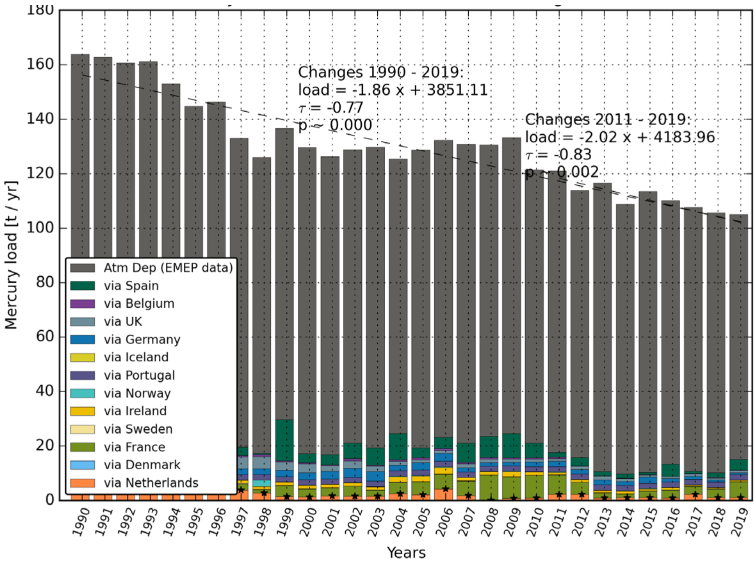


Figure c: Total mercury inputs to the OSPAR Maritime Area

This comprises waterborne inputs from OSPAR countries and modelled estimates of atmospheric deposition. Waterborne data have been flow normalised to the average riverine input 1990 - 2019. Notes: French data do not show actual inputs because limits of quantification are too high; Belgian data include a change from measuring total mercury to dissolved mercury; only two years of Danish data were available, which were excluded at Denmark's request. Flow normalisation is at the level of individual rivers which can mean that some national totals include mean values for missing rivers.

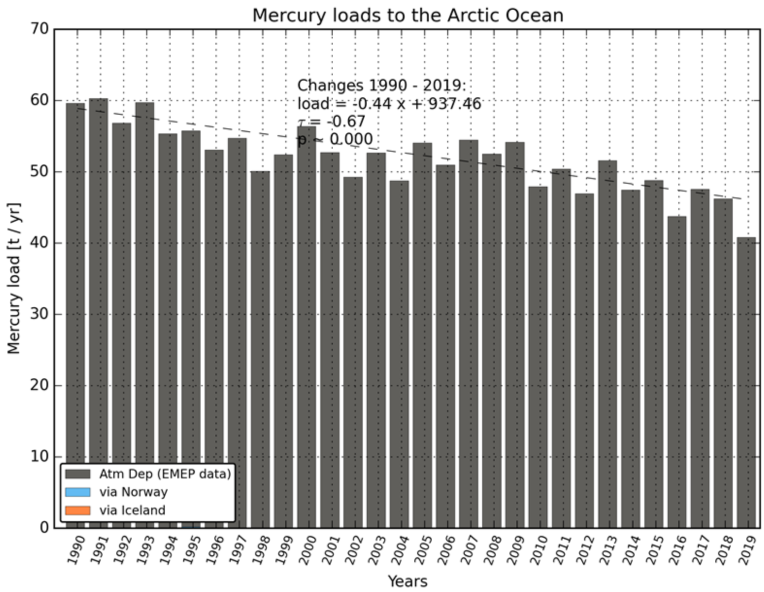


Figure d: Total mercury inputs to the Arctic Ocean

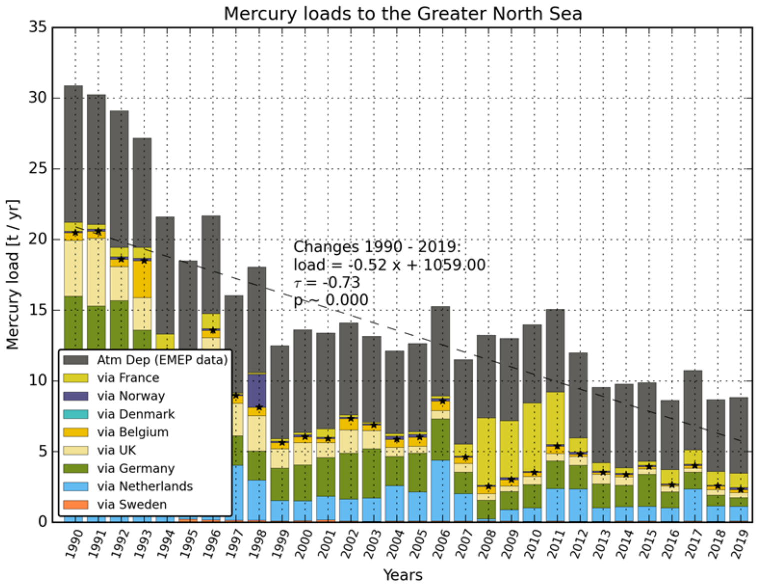


Figure e: Total mercury inputs to the Greater North Sea

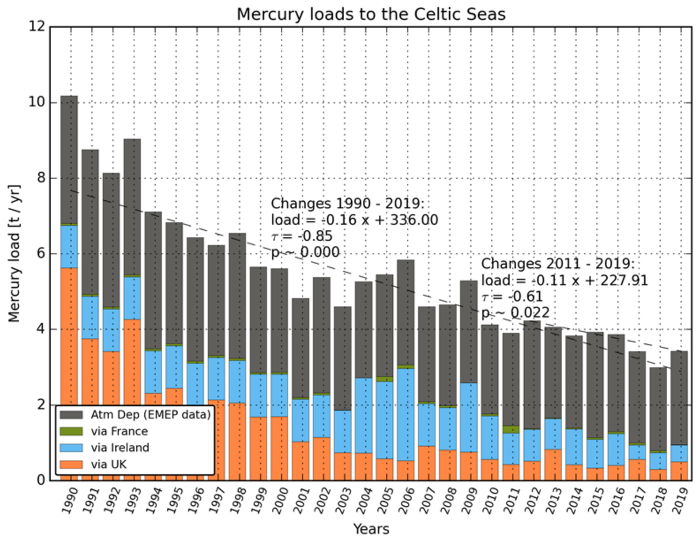


Figure f: Total mercury inputs to the Celtic Seas

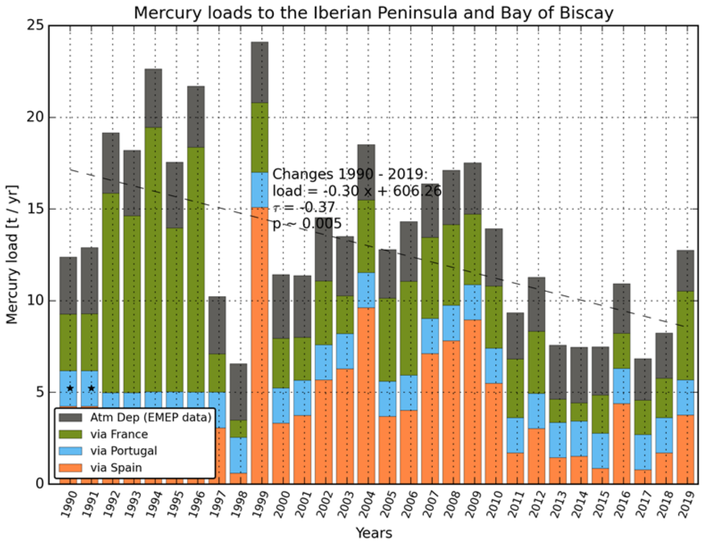


Figure g: Total mercury inputs to the Iberian Peninsula and Bay of Biscay

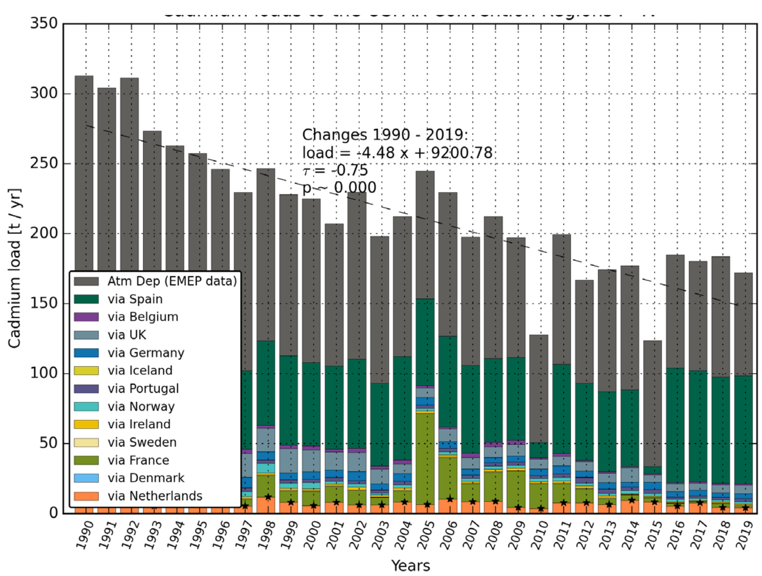


Figure h: Total cadmium inputs to the OSPAR Maritime Area

This comprises waterborne inputs from OSPAR countries and modelled estimates of atmospheric deposition. Waterborne data have been flow normalised to the average riverine input 1990 - 2019. Notes: French data do not show actual inputs because limits of quantification are too high; only two years of Danish data were available, which were excluded at Denmark's request. Flow normalisation is at the level of individual rivers which can mean that some national totals include mean values for missing rivers.

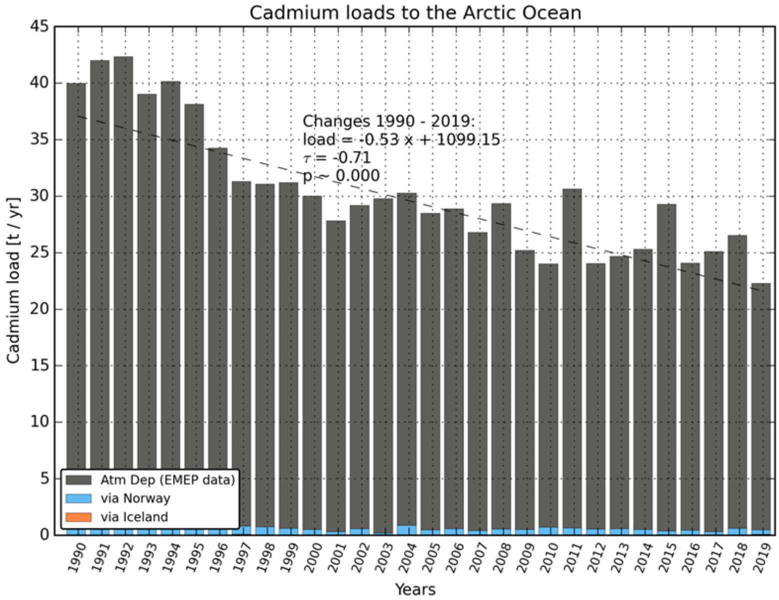


Figure i: Total cadmium inputs to the Arctic Ocean

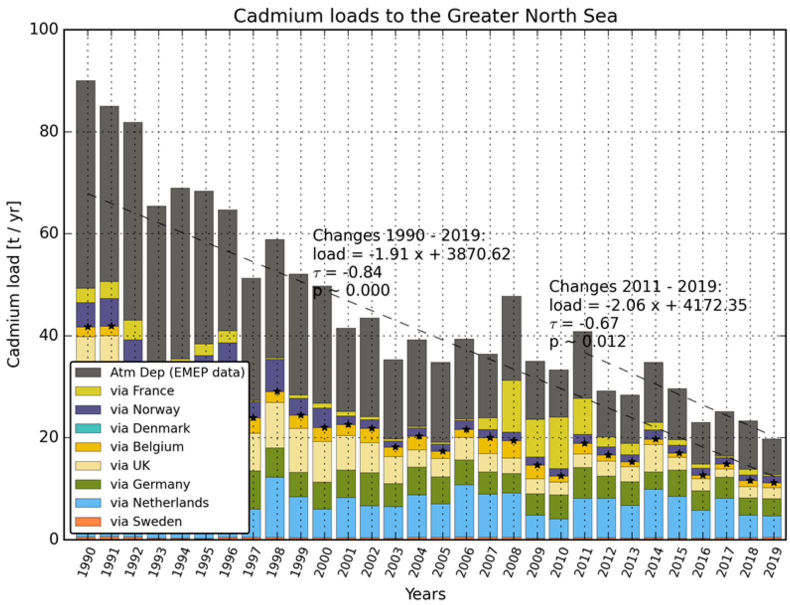


Figure j: Total cadmium inputs to the Greater North Sea

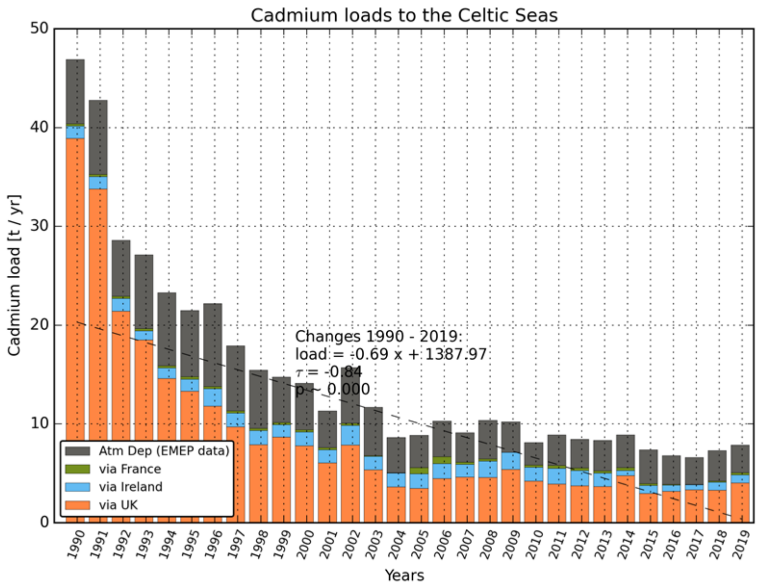


Figure k: Total cadmium inputs to the Celtic Seas

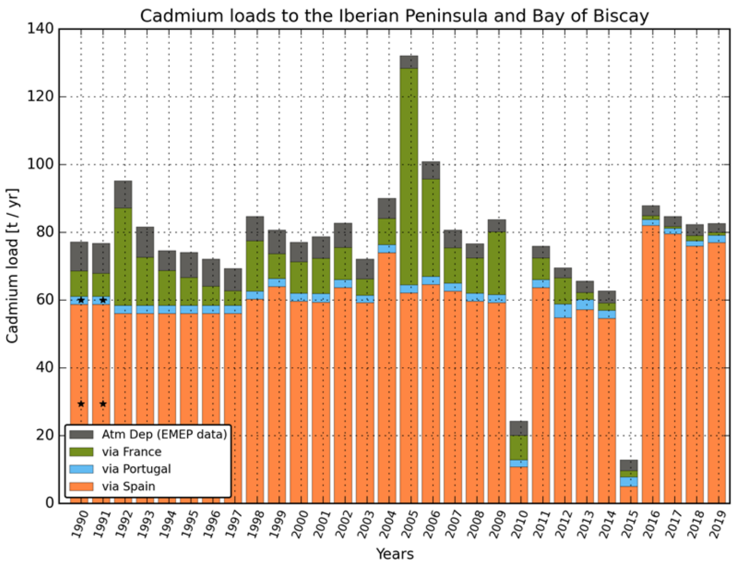


Figure l: Total cadmium inputs to the Iberian Peninsula and Bay of Biscay

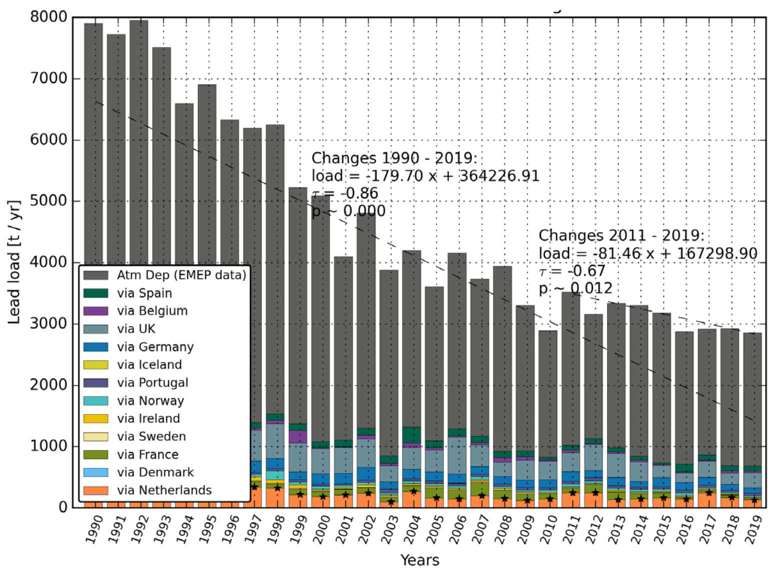


Figure m: Total lead inputs to the OSPAR Maritime Area

This comprises waterborne inputs from OSPAR countries and modelled estimates of atmospheric deposition Waterborne data have been flow normalised to the average riverine input 1990 - 2019. Notes: only two years of Danish data were available, which were excluded at Denmark's request. Flow normalisation is at the level of individual rivers which can mean that some national totals include mean values for missing rivers.

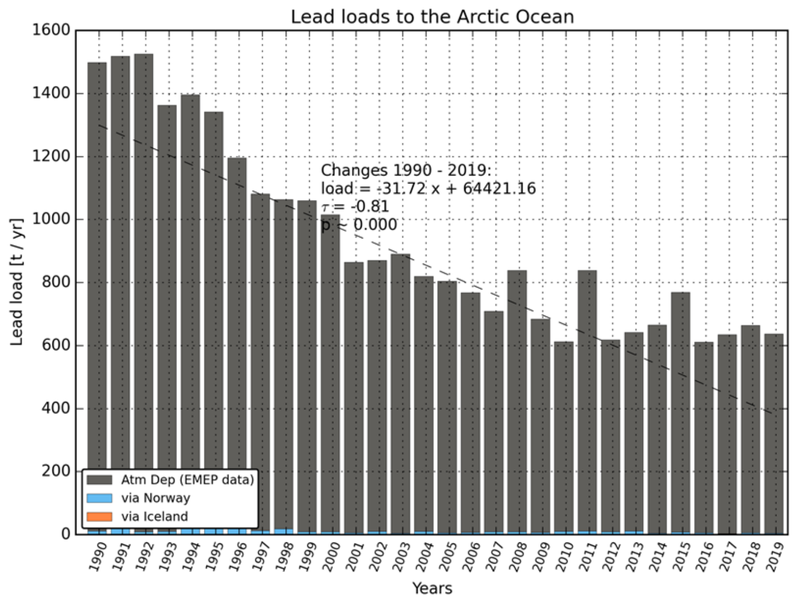


Figure n: Total lead inputs to the Arctic Ocean

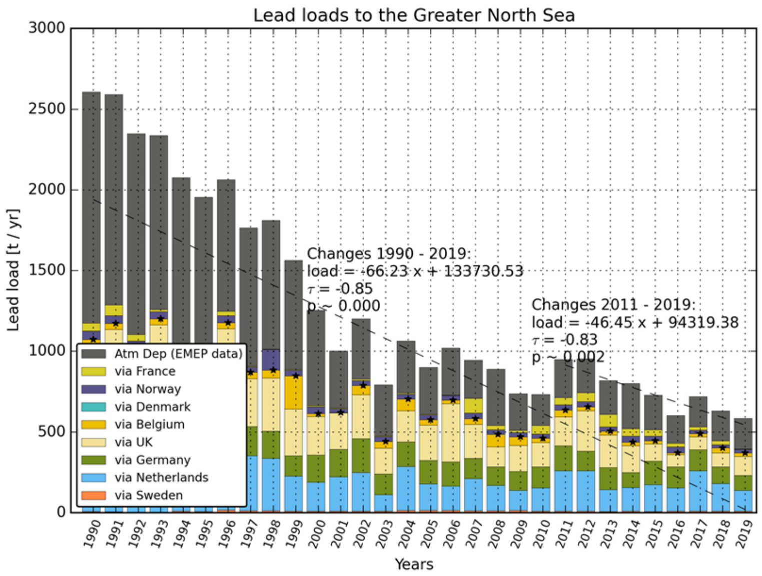


Figure o: Total lead inputs to the Greater North Sea

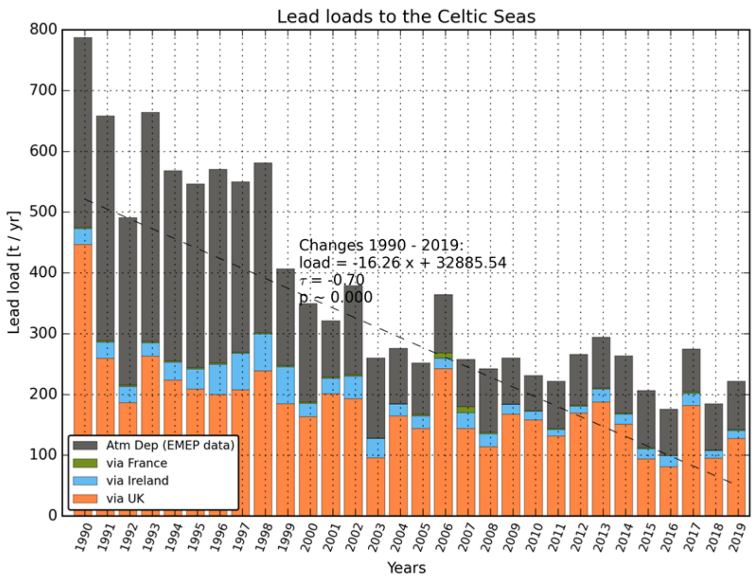


Figure p: Total lead inputs to the Celtic Seas

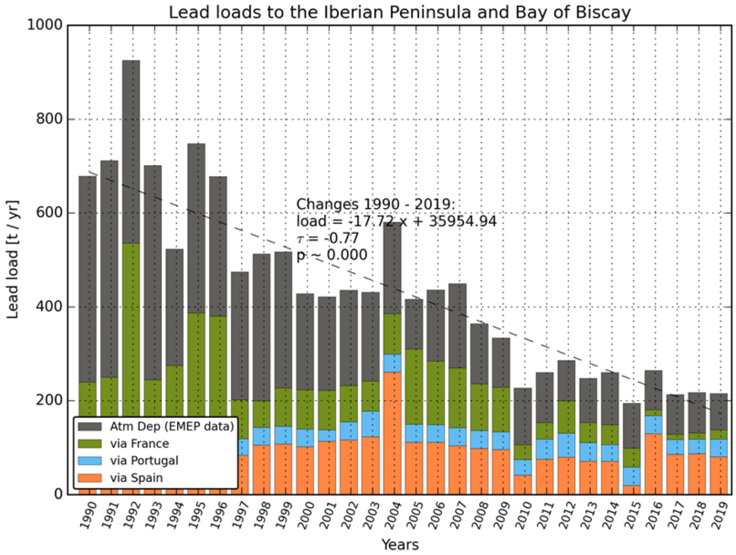


Figure q: Total lead inputs to the Iberian Peninsula and Bay of Biscay

Atmospheric pathways remain important, despite progress made under the 1998 Aarhus Protocol and its 2012 amendment, which introduces the requirement for Best Available Techniques (UNECE, 2012). Re-suspended material and sources from outside the OSPAR Maritime Area are particularly significant sources of mercury and lead.

Although there have apparently been rapid improvements in reducing inputs of mercury (**Figure c , Figure d, Figure e, Figure f and Figure g**), cadmium (**Figure h, Figure i, Figure j, Figure k and Figure l**), and lead (**Figure m, Figure n, Figure o, Figure p and Figure q**) to the OSPAR Maritime Area since 1990, changes since about 2007 have been minor, suggesting that most cost-effective measures have probably now been implemented and achieving further reductions will be challenging.

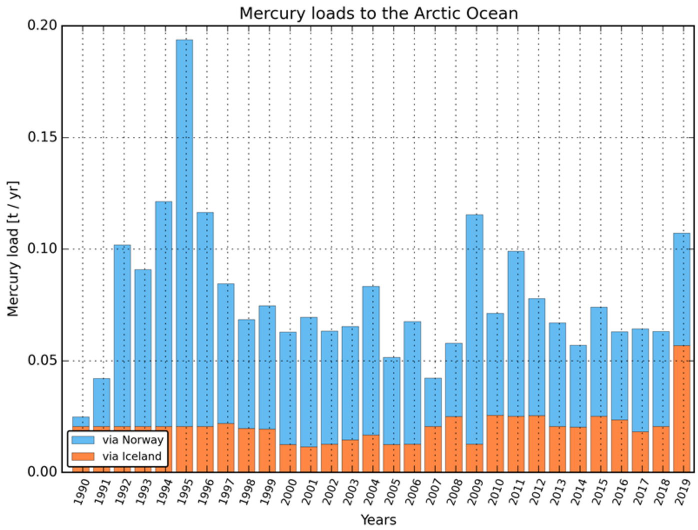


Figure r: Waterborne inputs of mercury to OSPAR's Region I (Arctic Waters)

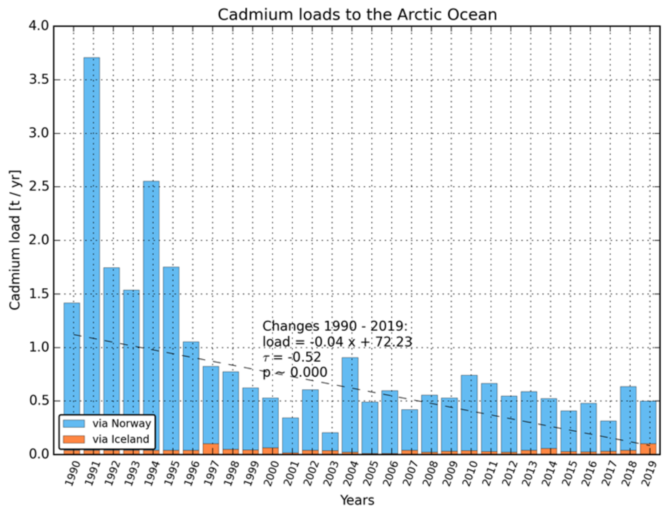


Figure s: Waterborne inputs of cadmium to OSPAR's Region I (Arctic Waters)

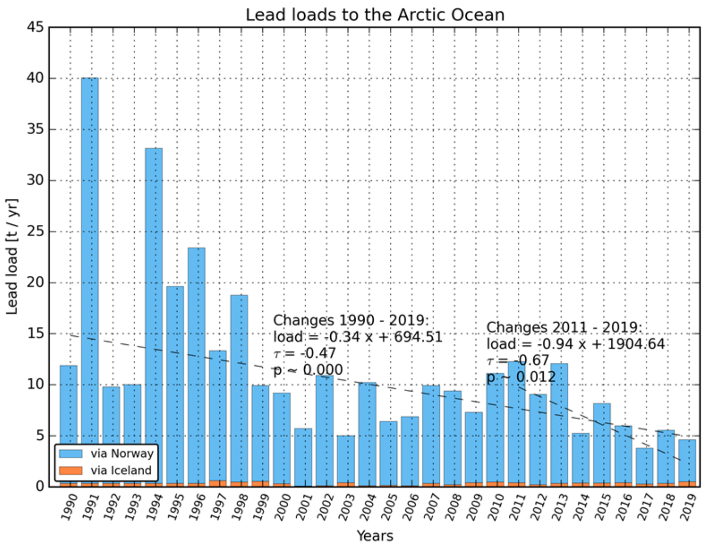
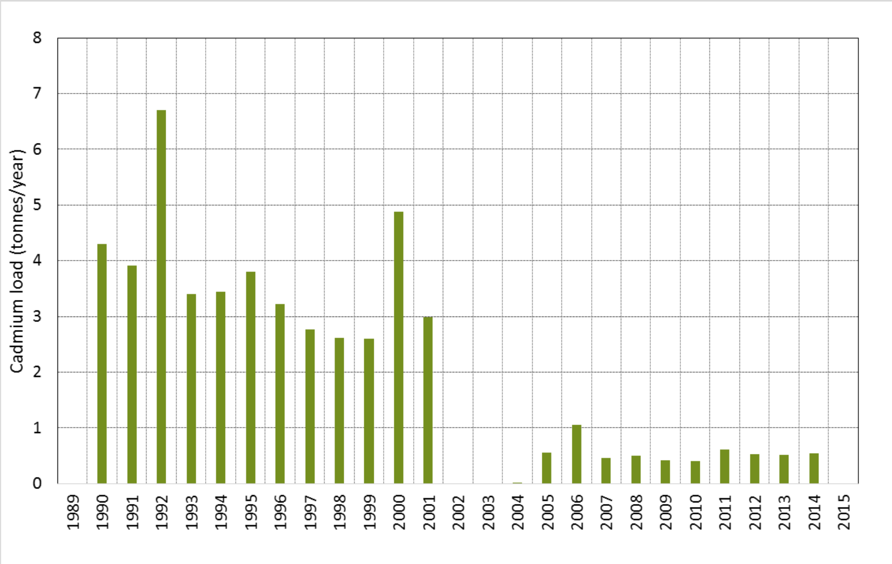


Figure t: Waterborne inputs of lead to OSPAR's Region I (Arctic Waters)

Changing limits of quantification have a substantial effect on the time series, and can result in the generation of an apparent trend unconnected to the actual inputs to the marine environment. **Figure u** shows an example using Belgian data, where greatly improved quantification limits in 2004 give an apparent input reduction compared to the previous period. While inputs may have reduced during this period, any real improvements are masked due to the inputs being overestimated prior to 2002. Overestimation occurs when the limit of quantification for an analysis is higher than the actual concentration of the substance in the environment. In this case, the assumed concentration is taken to be the mid-point between the upper and lower concentration estimates, which is then multiplied by the flow to estimate the input.



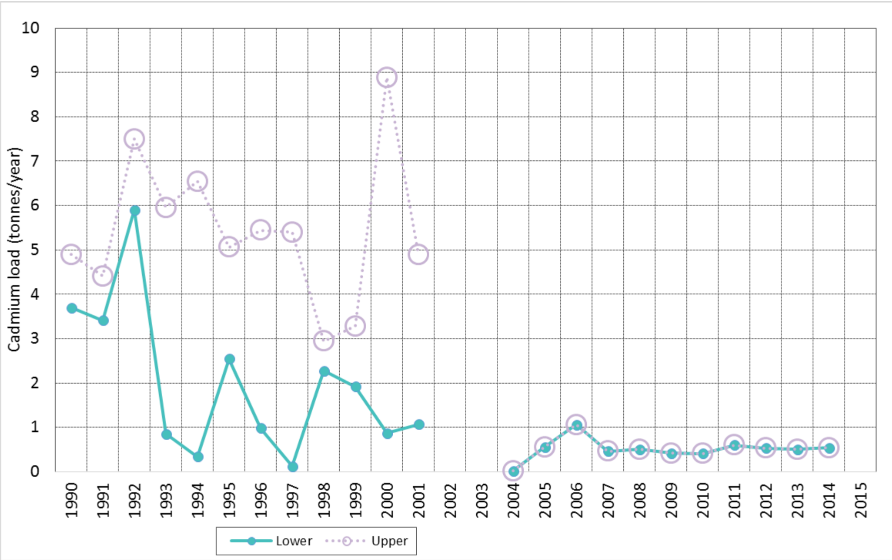


Figure u: Illustration of the effect of changes in limit of quantification on estimated total inputs
Estimated total cadmium inputs to the Greater North Sea 1990–2014 for Belgium (upper panel) based on riverine inputs (lower panel) with upper and lower estimates. The total inputs are calculated from the average of the upper and lower riverine input estimates (plus direct discharges). If the upper estimate is unreasonably high due to poor laboratory quantification limits, then the resulting input estimate is also over-estimated. In this case, this results in an (apparently statistically significant) downward trend that should only be attributed to improved laboratory practice rather than reduced inputs to the environment

A similar problem occurs where some countries have changed analysis matrix since the introduction of the European Union Water Framework Directive (EC, 2000). Environmental Quality Standards for metals under the Water Framework Directive were derived for the liquid fraction only. As a result, some countries have stopped measuring total metal concentrations and concentrate solely on the dissolved phase. This also has the effect of introducing an apparent reduction in inputs affecting the results.

These issues highlight the importance, when changing analysis laboratory or method, to consider whether limits of determination and quantification are maintained, so as not to introduce false trends into time series.

Confidence assessment

There is low confidence in the data used for this assessment. Monitoring, analysis, and reporting are well established throughout the OSPAR area. Despite this, there remain issues with differences in laboratory procedures, insufficient spatial coverage and possible missing sources (especially for direct discharges). In addition, historical data analysed using poorer methods are extremely uncertain, particularly in the case of mercury and cadmium. It is unlikely that Spain is as significant a source of cadmium as the data suggests.

There is moderate confidence in the methodology, which is straightforward, and the same as that used for the Inputs of Nutrients indicator assessment.

Conclusion

Les efforts importants des pays OSPAR depuis 1990 ont permis de réduire les émissions et apports de mercure (-40%), de cadmium (-45%) et de plomb (-66%) dans la zone maritime OSPAR. En ce qui concerne le mercure, les apports atmosphériques sont plus importants que les apports fluviaux, et les mesures prises ont été plus efficaces dans la réduction des émissions aquatiques qu'atmosphériques. Pour le plomb, les mesures de réduction d'émissions atmosphériques ont été si efficaces que les apports aquatiques sont désormais plus importants, sauf dans l'Arctique.
Ces résultats semblent montrer des progrès dans la prévention de la pollution marine. La réduction des apports atmosphériques au niveau régional est d'une grande importance pour atteindre les objectifs fixés dans la Stratégie environnementale pour l'Atlantique du Nord-Est 2030 de OSPAR.

Conclusion (version étendue)

In all Regions, inputs of heavy metals via both water and air to the OSPAR Maritime Area have decreased while the total input of atmospheric mercury and lead from the atmosphere remain greater than the waterborne inputs from OSPAR countries. Waterborne pathways for cadmium still dominate over the atmospheric, except in the Arctic. Even waterborne cadmium inputs have been substantially reduced to the Greater North Sea and Celtic Seas (OSPAR Regions II and III) and can be expected to reduce further with the standards proposed in the new EU fertilizers regulations 2019/1009.

OSPAR countries have been most successful in reducing atmospheric lead inputs, which have reduced by approximately 75 - 85% to the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast (OSPAR Regions II, III and IV) between 1990 to 94 and 2015 to 2019. In comparison, waterborne lead inputs to these Regions have "only" reduced 55 – 60% over the same period. Secondary atmospheric pollution from re-suspended material and from sources outside the OSPAR Maritime Area are now the major sources of airborne pollution and there is a need for cooperation beyond OSPAR's boundaries to manage these in addition to the waterborne inputs.

Heavy metal input estimates are very uncertain, particularly for mercury and cadmium. Quantification limits vary between laboratories within countries, and as laboratories or methods change. This causes substantial changes in the estimated inputs. These uncertainties were greater at the beginning of the analysis period. Despite the methodological issues for mercury and cadmium, with measurement techniques that are close to detection limits, the monitoring data for the suite of heavy metals show substantial waterborne input reductions.

Lacunes dans les connaissances

Des contrôles de qualité strictes sont nécessaires dans les laboratoires chargés de l'analyse des échantillons de métaux lourds. Des limites de détection élevées peuvent entraîner une surestimation des apports et entraver la détection des modifications. Lorsque l'on envisage de changer de laboratoire d'analyse il faudrait évaluer les effets sur les limites de quantification.

Il existe un décalage entre les exigences de la Directive cadre sur l'eau de l'Union européenne, s'agissant de mesurer les teneurs en métaux dans la fraction dissoute, et l'Accord OSPAR 2014-04 pour quantifier les apports totaux de métaux lourds.

Des lacunes subsistent quant aux connaissances liées à la rétention et l'exportation de métaux lourds dans les estuaires, limitant les connaissances de la proportion de métaux parvenant dans le milieu marin.

Les connaissances sur les pertes de métaux lourds provenant de ports, de la navigation, d'immersions historiques et d'autres sources potentielles sont limitées.

Lacunes dans les connaissances (version étendue)

Reference levels and targets need to be set to quantify the natural background inputs of mercury, cadmium, and lead and to improve harmonisation with the European Union Water Framework Directive.

Data from the Riverine Inputs and Direct Discharges Monitoring (RID) programme (OSPAR Agreement 2014-04) need to be more widely used to ensure that any data problems or gaps are identified and addressed as quickly as possible.

Modelled atmospheric deposition is validated using daily deposition observations from the European Monitoring and Evaluation Programme (EMEP) chemical network. However, this network is land-based and therefore the quality of the model products is less well validated over the sea surface. Overlapping the EMEP observation network are the OSPAR Comprehensive Atmospheric Monitoring Programme (CAMP) monitoring stations. These are coastal stations, which can be considered to be more representative of marine deposition, but with a lower (often monthly) monitoring frequency.

Waterborne inputs are based on a combination of observed (monitoring at the river mouth), modelled (unmonitored areas) and point source inputs. Observations are based on 12 chemical analyses per substance and year combined with modelled or observed flow data. While monitoring and analysis follow OSPAR RID guidelines and can be considered to represent the 'best' input estimate, uncertainties in the relation between chemical concentration and run-off, together with analytical and flow uncertainties mean that estimated uncertainty may be in the region of 100–200%.

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Métadonnées d'évaluation

Champ	Type de données	
Type d'évaluation	Liste	Évaluation d'indicateur
Indicateur ODD	Liste	14.1 D'ici à 2025, prévenir et réduire nettement la pollution marine de tous types, en particulier celle résultant des activités terrestres, y compris les déchets en mer et la pollution par les nutriments
Activité thématique	Liste	Substances Dangereuses
Documentation OSPAR pertinente	Texte	OSPAR Agreement 1997-08. Guidelines for the sampling and analysis of mercury in air and precipitation OSPAR Agreement 2010-03. The North-East Atlantic Environment Strategy; Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020 OSPAR Agreement 2014-04. Riverine Inputs and Direct Discharges Monitoring Programme (RID) applicable from 1 January 2015 OSPAR Agreement 2015-04. Guidance for the Comprehensive Atmospheric Monitoring Programme (CAMP) OSPAR Agreement 2016-01. Coordinated Environmental Monitoring Programme (CEMP), as revised OSPAR Agreement 2021-01. The North-East Atlantic Environment Strategy; Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2030
Date de publication	Date	2022-06-30
Conditions d'accès et d'utilisation	URL	https://oap.ospar.org/fr/politique-de-donnees/
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Résultats des données	Fichier Zip	https://odims.ospar.org/en/submissions/ospar_heavy_metals_results_2022_06/
Source des données	URL	https://www.emep.int/ https://www.nibio.no/en

Bilan de santé d'OSPAR 2023

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Notre vision est celle d'un océan Atlantique Nord-Est propre, sain et biologiquement diversifié, qui soit productif, utilisé de manière durable et résilient au changement climatique et à l'acidification des océans.

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