Cadmium in the EU: A 50-Year Environmental Success Story

For decades, cadmium has been viewed as an important environmental pollutant associated with the metals industry. While this may have been true in the past, the picture in Europe today is very different.

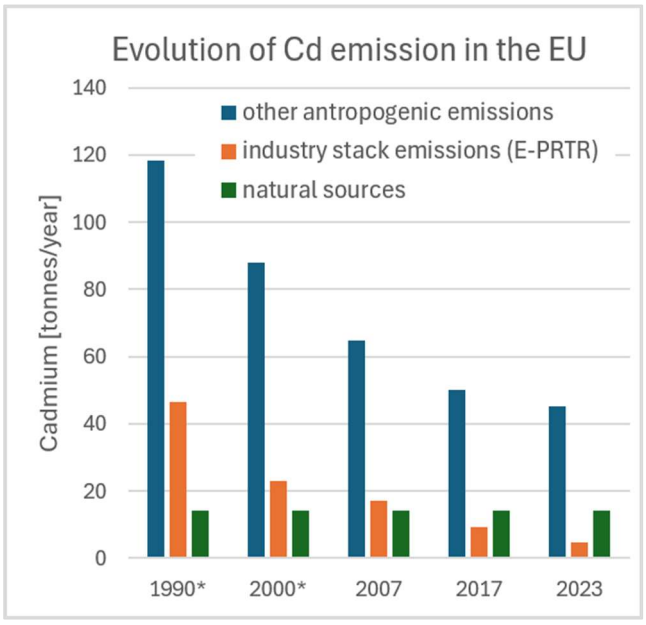
Over the last fifty years, strict environmental regulations, major investments in cleaner technologies, improved gas capturing and filtration systems, and advanced wastewater treatment have driven a remarkable decline in industrial cadmium emissions. As a result, industrial releases to both air and water have decreased to historically low levels. In fact they now stand at less than 30% of the cadmium emission cap of the 1998 UN Aarhus protocol – a binding agreement of participating countries to cut their mercury, cadmium and lead emissions below their 1990 baseline levels.

Today, cadmium emissions from natural sources are now the most significant source of cadmium emitted to air while soil erosion now contributes substantially more cadmium to rivers and surface waters than direct industrial discharges.

Understanding these changes is important for ensuring that future environmental policies focus on the largest remaining sources of cadmium rather than on activities that have already been properly controlled and for which the contribution to the overall EU cadmium environmental releases are very small.

Natural Emissions of Cadmium in the Atmosphere

Cadmium is a naturally occurring element that is present in the Earth's crust. As such, it is cycled through the environment.



Natural cadmium enters the atmosphere through:

- Wind-blown soil and dust
- Natural weathering processes
- Forest and vegetation fires
- Volcanic activity
- Sea spray and other natural mechanisms

Natural emissions to air were derived from rainwater sampling in the EU in 2017 (EMEP). That year, a total of 73.7 tonnes of cadmium was present in rainwater. This compares to 9 tonnes from IED industry stack emissions and 50.5 tonnes of other anthropogenic emissions calculated by LR-TAP. Therefore, 14.2 t/y can be assigned to emissions of cadmium from natural sources.

Figure 1. Evolution of Cadmium emission to air from anthropogenic and from natural sources (LR-TAP)

Since 2016, the total amount of reported cadmium emissions by E-PRTR has become less than emissions from natural sources, highlighting the significant efforts made by industry to address cadmium emissions.

Industrial Cadmium Emissions Have Fallen by More Than 95%

***Emission reporting in the EU:** two distinct reporting of EU emissions*

E-PRTR and IEP (European Pollutant Release and Transfer Register and Industrial Emissions Portal)

*This report is related to annual mandatory industrial reportings of **measured stack emissions,** in case they are exceeding 10 kg Cd/y. Reported emissions are **mostly from larger companies** for which emissions are regulated under the EU Industrial Emissions Directive and for which emission limit values are set in their environmental permit. Examples of covered sectors are steel and non-ferrous metals, chemicals, energy, minerals, waste and wase water, wood and paper. E-PRTR created in 2007 will migrate to the IEP in 2028.*

LR-TAP

*This annual EU emission inventory report comprise the EU's official submission to the United Nations Economic Commission for Europe (UNECE) Convention on **L**ong-**R**ange **T**ransboundary **A**ir **P**ollution (Air Convention) (UNECE, 1979). The LR-TAP report is covering **stacked and diffuse emission from all industrial and non-industrial activities** in the EU. The reported emission are a mix of **measured emissions and emissions modelled** from the size of the activities by applying specific emissions factors to each activity. The size of the activities is updated annually while the emission factors are reviewed every 3 to 4 years. The LR-TAP reporting started from the reference year 1990.*

During the 1970s, EU industrial activities released an estimated 1,500 tonnes of cadmium to the atmosphere each year. In 2024, industrial emissions modelled and reported under LR-TAP* had fallen to approximately 49 tonnes, while measured and reported stack emissions from industry reported under E-PRTR* dropped to 5.7 tonnes

The decline reflects decades of investment in:

- Modern air filtration systems
- Emission control technologies
- Process improvements
- Recycling and resource efficiency

When comparing emissions in the E-PRTR and LR-TAP reports, it shows that measured emissions from larger companies have decreased faster than total emissions.

In 2007, when E-PRTR reporting started, measured industrial emissions were at 20% of the total emission in LR-TAP.

In 2024, this ratio had fallen to merely 11%.

LR-TAP emissions include those from transport, non-industrial activities and households (30% of all emissions) as well as diffuse industrial emissions for which it is a challenge to assess them accurately. The ratio E-PRTR/LR-TAP has decreased over time which might indicate that the emissions factors used in LR-TAP are not following the environmental progress made by industry.

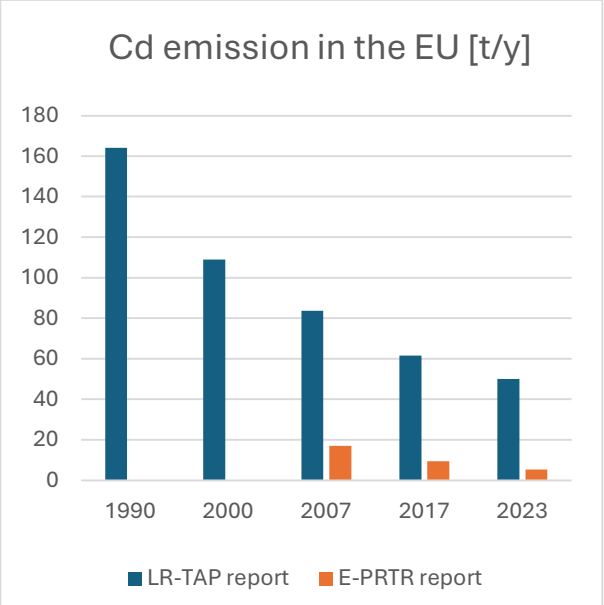


Figure 2. Anthropogenic cadmium emissions to air

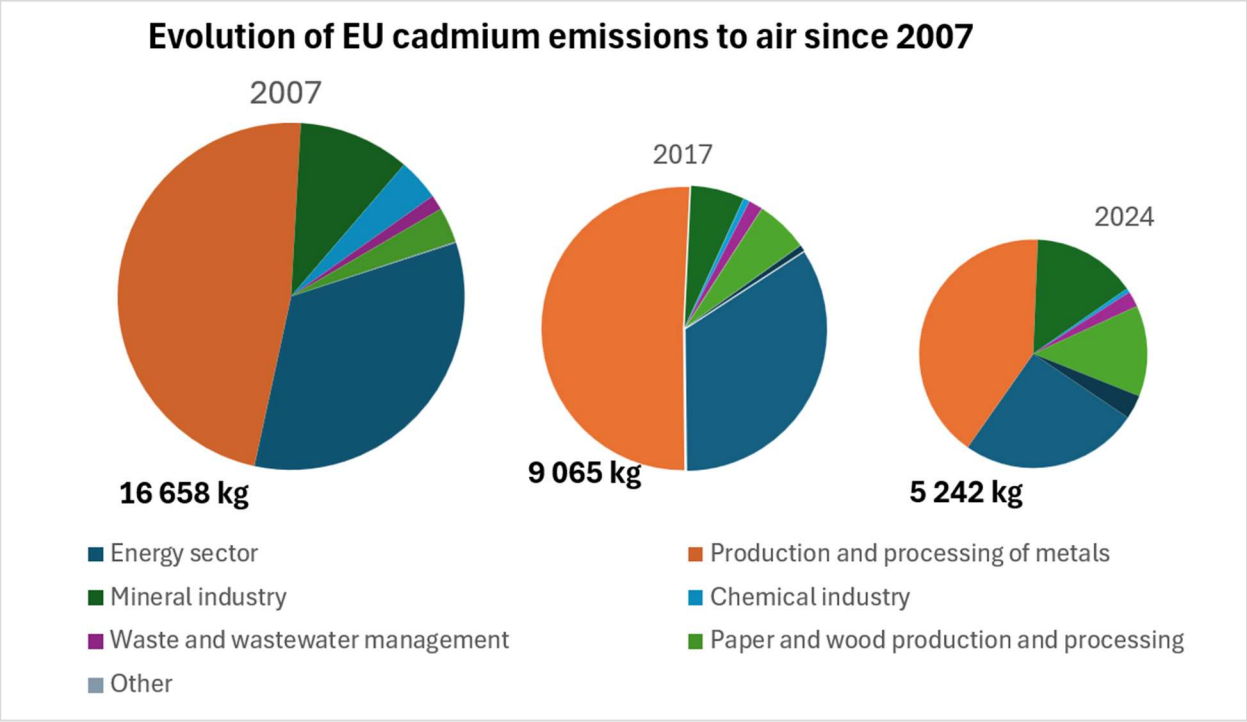


Figure 3. Sources of industrial cadmium emissions to air; evolution since 2007 (source E-PRTR)

Key takeaway: All industrial sectors have made significant progress in reducing cadmium emissions to air. Today, cadmium emissions from natural sources are 2.5 higher than the measured industry stack emissions reported in E-PRTR.

Soil Erosion Is Now the Largest Source of Cadmium to Rivers

One of the most important but least know facts about cadmium is that it occurs naturally in soils.

When rain falls on agricultural land, forests and natural landscapes, small amounts of soil are transported into streams, rivers and lakes. This process, known as soil erosion, carries cadmium that is a natural constituent of the soil.

Today, natural soil erosion contributes more than 10 times as much cadmium to surface waters as industrial discharges.

The amount of cadmium from industrial waste water (2.8 t/y) released into surface waters is similar to the amount of cadmium directly deposited on EU surface waters through atmospheric dust and precipitation (2 t/y).

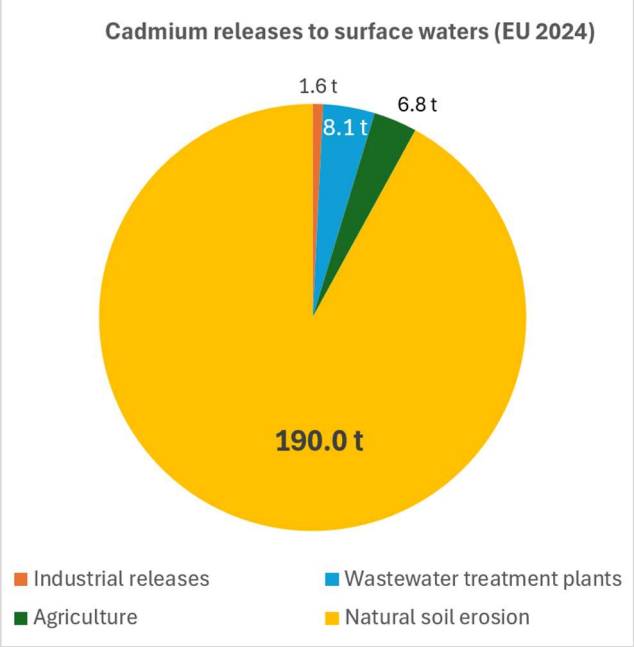
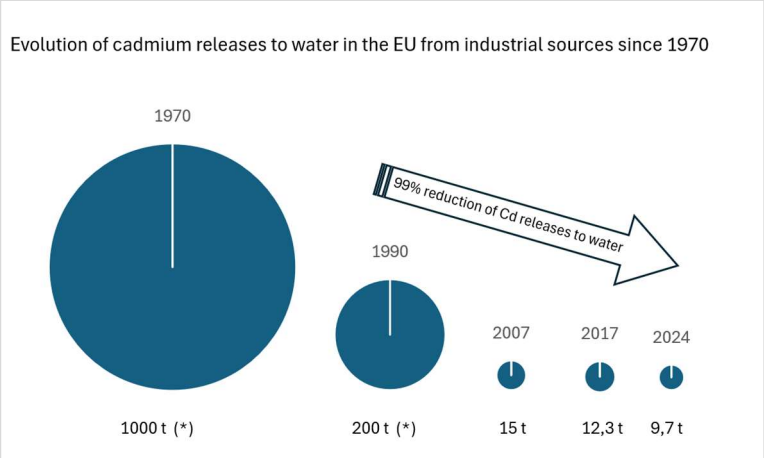


Figure 4. Sources of Cadmium Entering Surface Waters. (source: Camber 2021, E-PRTR)

Industrial Releases to Water Have Declined Sharply With 98.5%

The cadmium releases to rivers and surface waters from industry have also dramatically decreased to 1.5% of the 1970s levels, reaching 15.6 t in 2024. The share originating from the metals industry is now at 356 kg Cd, merely 2.3% of all reported releases.



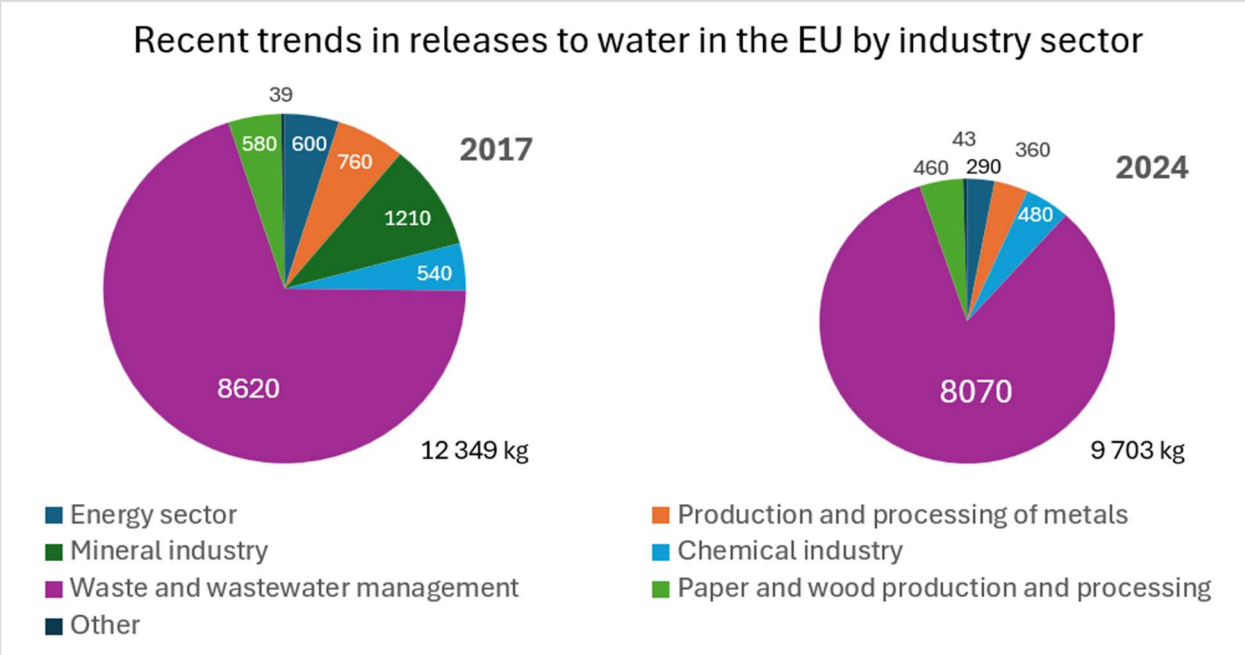
Modern industrial facilities now incorporate:

- Closed-loop water systems
- Advanced waste water treatment
- Recovery and recycling technologies
- Continuous environmental monitoring

As a result, industrial cadmium releases to water have declined by more than 99% over the past 50 years.

Figure 5. Evolution of industrial releases of cadmium to surface water in the EU since 1970. (source: E-PRTR)
(*)=estimated value based on extrapolation from available regional data

Figure 6 show the further decrease in emissions from most sectors, and above all, mineral



and metals industry.

Figure 6 Cadmium releases to Water by industrial sector [kg Cd/year] (source: E-PRTR)

Key takeaway: Erosion of soils results in natural releases of cadmium present in the soils. The amount of Cd released by soil erosion now greatly exceeds direct industrial Cd-releases to surface waters.

As a result, only a small share of cadmium entering European surface waters is originating from industrial facilities.

Cadmium refining and processing industry have only a very small share in cadmium emissions to air and releases to water

Industrial emissions of cadmium to air are mostly related to presence of cadmium as a natural occurring impurity in oil, coal and metal mineral concentrates.

Cadmium is recovered as a by-product from the smelting and refining of zinc mineral concentrates as well as from recycling nicad batteries, for which there are dedicated collection and recycling facilities in place in the EU, ensuring +90% cadmium recovery rates.

Downstream users of cadmium in the EU are NiCd battery manufacturers, cadmium platers, specialty alloy manufacturers and manufacturing of detectors.

While in the EU, 89% is used for NiCd batteries and 11% for plating in the aeronautic, military and offshore sector, there is less than a ton of cadmium used in the other applications.

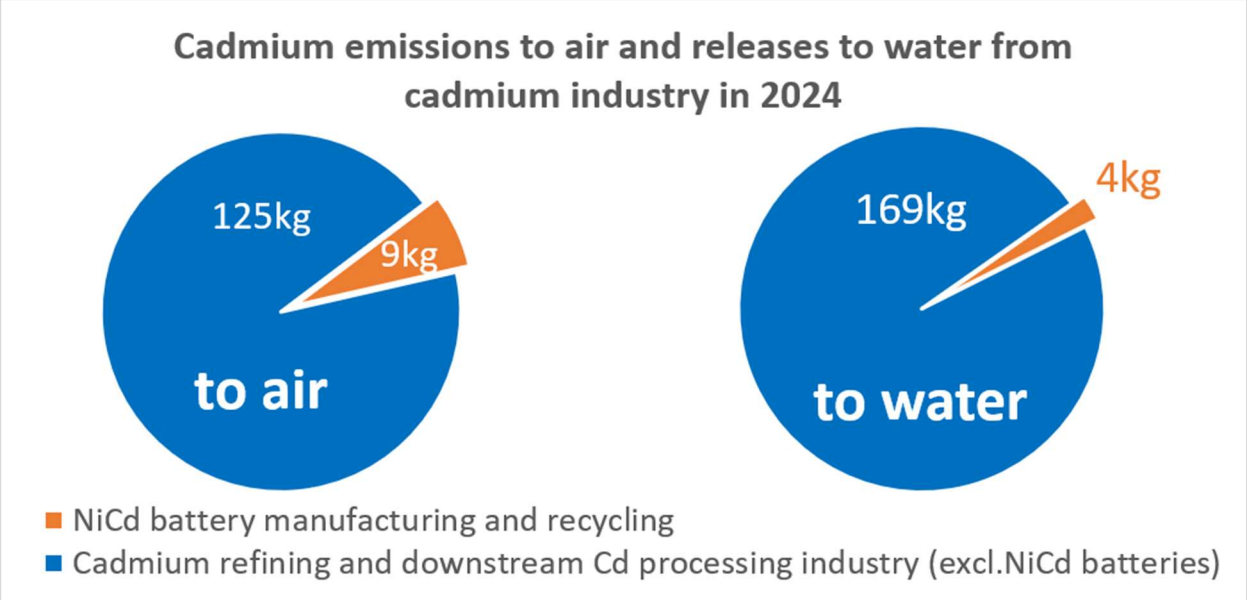


Figure 7. Cadmium emissions to air and releases to water from Cd refining and processing industry

Another significant EU use of cadmium, but no longer manufactured in the EU, are cadmium pigments, imported from the UK and China, These imported products count for approximately 100 t/y of cadmium.

Of the total industrial cadmium emission to air by industry (5.3 t, see fig 3), the emissions from the intended use of cadmium by the above-mentioned activities was 134 kg in 2024 or 2.5% of total industry emissions.

Emissions to air from NiCd battery manufacturing and recycling were at 9.1 kg in 2024 while releases to water were at 4 kg. Less than 6% of the Cd emissions to air from the metals industry is related to zinc and cadmium refining and use.

Of the total industrial releases of cadmium to water (15 600 kg, fig. 6) the contribution from the Cd industry was 173 kg or 1.1% of total industry. Almost half of the Cd release to water from the metals industry is originating from zinc and cadmium refining and its downstream uses.

Key takeaway: Less than 0.1% of reported industrial cadmium releases to the environment in the EU originates from NiCd battery manufacturing and its recycling.

What about the environmental impact of Cadmium in fertilizers and risk of unsafe levels of cadmium entering the food chain

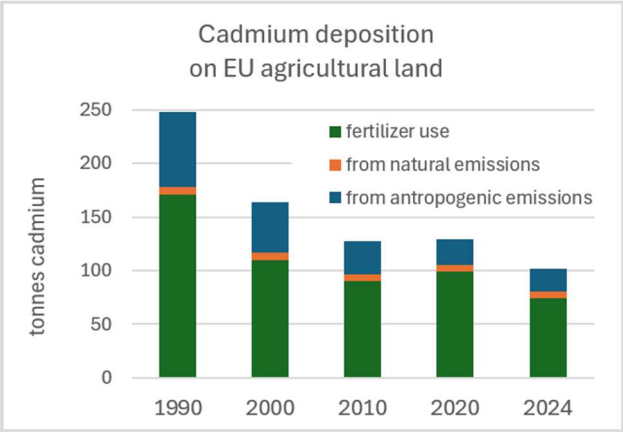


Figure 8. Evolution of cadmium deposits on EU agricultural soil

Public discussion often focuses on cadmium in phosphate fertilizers. Average Cd content in EU phosphate fertilizers is 36 mg Cd/t P_2O_5. The EU has set a maximum limit of 60 mg of cadmium per kg of P_2O_5 for CE-marked phosphate fertilizers under the EU Fertilising Products Regulation.

The total annual cadmium deposit in agricultural soils decreased by more than 40% since 2000, thanks to a reduction of phosphate fertilizers use and the result of cleaner air policies.

Today's EU median Cd concentration is agricultural topsoil is at 0.18 mg Cd/kg. The threshold concentration for cadmium in agricultural and grassland is at 1 mg/kg. A high annual use of fertilizers (20 kg P/ha) could result in an increase of cadmium in topsoil with 0.06mg/kg soil after 100 years. In reality, cadmium accumulation will be lower and even negative as cadmium is also immobilized, leached out and some is taken up by crops.

An EU soil sampling in 2008 in the GEMAS project (Geochemical Mapping of Agricultural and Grazing Land Soil) concluded that 2.3% of the agricultural land and 4.5% of the grazing land have levels of cadmium exceeding 1 mg/kg. According to the LUCAS topsoil database (2009-2018), managed by Eurostat, JRC, and the European Soil Data Centre (ESDAC), 5.5% of all EU land has cadmium concentration exceeding 1 mg/kg.

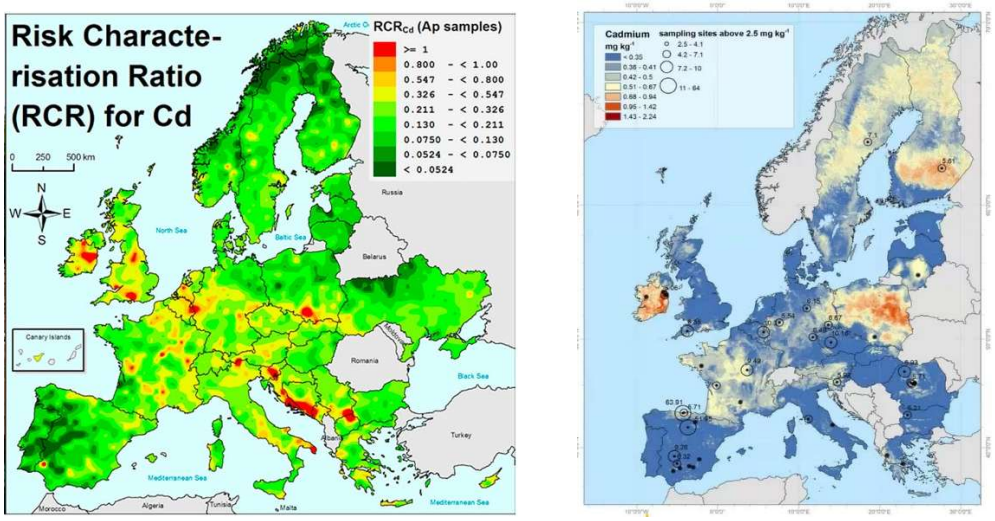


Figure 9. Cadmium mapping in EU agricultural soil by GEMAS (left) and Lucas (right)

Apart from soil monitoring, there are safe thresholds set for cadmium in food. When these thresholds are exceeded, contaminated crops are destroyed to ensure health of the population.

Key takeaway: While cadmium in phosphate fertilizers receives considerable policy attention, the annual cadmium deposition on agricultural land has decreased by 40% since 2000 due to a reduced use of phosphate fertilizers as well as by cleaner air. Food standards set maximum levels to protect consumers.

Looking forward

Anthropogenic emissions and exposure to cadmium are expected to continue their downward trend through the implementation of a set of European and worldwide established measures:

- The EU **Industrial emissions Directive** (IED) sets limit values for environmental emissions
- The EU **Water Framework Directive** (WFD) obliges member states to achieve and maintain a "good status" for all European surface and groundwater bodies.
- The EU **Soil Monitoring Law** aims for healthy and resilient soils across the European Union by 2050
- The EU **Battery Regulation** governs the entire lifecycle of all batteries sold in the European Union, which includes manufacturing, collection and recycling of NiCad batteries.
- **REACH Regulation** restricts the use of cadmium in the EU
- The **RoHS Directive** set limits for cadmium in electrical and electronic equipment (EEE)
- The EU **Carcinogens, Mutagens and Reprotoxic Substances Directive (CMRD**) regulates workplace exposure to cadmium.
- The **Seveso III** Directive regulates industrial facilities storing or processing cadmium above a threshold tonnage.
- The 1998 **Aarhus Protocol** on Heavy Metals is a legally binding international treaty set up by UNECE specifically targeting cadmium emissions.
- The **Basel Convention** on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is a global UN treaty that plays a critical role in preventing the dumping of cadmium.
- Joint FAO/WHO Codex Alimentarius or "**Food Code**" Commission establishes international maximum permitted levels for cadmium contaminants in various foods to protect human health. In the EU, this is implemented into the **Food Contaminants Regulations**

ICdA and its members are committed to implement Best Available Technology (BAT) to protect the environment and to adequately manage workers' exposure to cadmium and as such contribute to a safer and healthier environment for all.

Looking at the Whole Picture

Cadmium will always exist in the environment because it is a naturally occurring element. The critical question is not whether cadmium is present, but where the most significant environmental releases originate that needs to be addressed.

The evidence from Europe shows a clear shift over time:

- Industrial emissions to air have fallen by more than 95%.
- Industrial releases to water have fallen by more than 98%.
- Today, natural sources represent the significant share in cadmium emissions to air.
- Soil erosion is the largest source of cadmium entering surface waters.
- Precipitation contribute around three times more cadmium to agricultural land than the use of phosphate fertilizers.
- The direct contribution of cadmium-producing and cadmium-using industries to cadmium pollution of air and water is now very small.

Conclusion

Europe's cadmium story is largely one of environmental progress.

Half a century ago, industrial sources were by far the main contributors of cadmium emissions. Today, after decades of technological improvements and regulatory action, industrial emissions have been reduced to a fraction of their former levels.

As industrial sources have declined, naturally occurring cadmium and diffuse environmental flows have become increasingly important in the overall cadmium cycle. Soil erosion now represent the largest sources of cadmium entering the surface waters.

Future policy discussions should therefore consider the full cadmium cycle and prioritize actions according to the relative size of each source. Only by focusing on the dominant contributors can environmental efforts deliver the greatest benefit for Europe's ecosystems and water resources.

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International Cadmium Association

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