European Environment Agency

European Commission

# Zero pollution monitoring and outlook 2025

EEA-JRC Report 13/2024

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

Joint Research Centre
Via Enrico Fermi 2749
TP262, I-21027 Ispra
Italy

Tel: +39 0332 789111
Web: joint-research-centre.ec.europa.eu/index_en
Contact: commission.europa.eu/about/contact_en



Luxembourg: Publications Office of the European Union, 2025

ISBN 978-92-9480-691-8
ISSN 1977-8449
doi:10.2800/6470682

Cover design: European Environment Agency
Cover image: © József Ölveti, Urban treasures/EEA
Layout: European Environment Agency

# Contents

# Forewords

Fifty years ago, Europe's environmental landscape looked very different with smog filled cities, heavily polluted waters and very degraded soils. That is why the first European Environment Action Programme was launched in the seventies to improve people's quality of life by reducing pollution and its health impacts.

Since then, we have made remarkable progress. Air quality has improved remarkably, with key pollutants reduced by 80% since the 1980s ([A]). Premature deaths in the EU-27 dropped from up to one million annually in the early 1990s to a bit under 240,000 in 2022. Water pollution has also been significantly curbed through strong legislation and investments in clean technology developed by European businesses and researchers.

I am encouraged by the latest data measuring pollution in the European Union. We are likely to meet nearly half of the zero pollution targets by 2030 with improvements in air quality, pesticides management and marine litter. I am also encouraged to see progress at regional level which is presented in the new dashboard ([B]). For example, 97% of EU regions have improved their air quality since 2016. Despite this, much work remains. Many Europeans still live in areas where air pollution exceeds WHO safety levels, plastic waste continues to accumulate in our oceans, and microplastics is a growing health concern. Member States must step up their efforts to make more progress on noise pollution, nitrogen deposition, microplastics and waste.

The second edition of the Zero pollution monitoring and outlook report, developed by the Commission's Joint Research Centre and the European Environment Agency, provides the latest evidence on the EU's progress towards zero pollution since 2022 and on what it takes to achieve the 2030 targets agreed under the European Green Deal. This is complemented by the first dashboard providing information on pollution levels where you live.

The EU has adopted many new pieces of legislation to contribute to the goal of achieving zero pollution. The focus is now on implementing them: only timely and ambitious delivery of what we have committed to will allow us to protect Europeans from dangerous levels of pollution.

In the new mandate of the European Commission, the objectives of reaching a non-toxic and clean environment are firmly anchored in the new priorities for a competitive and resilient Europe. The recently published Competitiveness compass, Clean industrial deal and Vision for agriculture and Food all underline the importance and opportunities for clean technologies and innovation to achieve the agreed goals. New initiatives like the European Water Resilience Strategy and the Ocean pact, the Circular economy act and the Chemical industry package will be crucial to address some of the shortcomings identified in this report.

I would like to thank the European Environment Agency and the Commission's Joint Research Centre for their excellent work. This report will guide our decision-making towards achieving zero pollution. It will help us to ensure that we stay on track to reduce pollution in air, freshwaters, seas and soil, while boosting the competitiveness of the EU clean tech industry, societal resilience and security.

**Jessika Roswall, Commissioner for Environment, Water Resilience and a Competitive Circular Economy**

([A]) Acid rain and air pollution: 50 years of progress in environmental science and policy

([B]) Towards zero pollution in regions

Reducing and removing pollution in the air, soil and water is fundamental to protecting public health, improving food security and preserving a healthy environment for future generations. To achieve that, the EU zero pollution action plan set key targets to be achieved by 2030. These include reducing the number of premature deaths caused by air pollution by 55%, improving soil quality by reducing nutrient losses and use of chemical pesticides by 50% and cutting plastic litter at sea by 50%.

This second edition of the Zero pollution monitoring and outlook report gives a snapshot of pollution in the EU today. It finds that we are on track in some areas to meet these ambitious targets but still face significant challenges in others.

Research and innovation are crucial to understanding pollution and its sources and consequences, and identifying which policy initiatives could best tackle it. The scientific evidence, monitoring and forecasting behind this report help us determine areas where action is needed most. For example, new models show that, by modifying our consumption patterns, we could slash our environmental impact and speed up progress towards zero pollution in the EU by 2050.

In order to be successful, efforts to reduce pollution must go hand in hand with economic sustainability. Competitiveness and growth are not at odds with environmental protection; however, devising the right policy initiatives to support both goals is a complex task. Science and innovation can guide us in this crucial and delicate process. A good example is the research-backed policies that will help us develop a truly circular economy capable of achieving these goals while reducing our dependence on imported raw materials.

With just 5 years to go to achieve our 2030 pollution targets, this report produced by the European Commission's Joint Research Centre and the European Environment Agency couldn't be more timely. I welcome its analysis of pollution in the EU today that will help inform and guide our policymaking on the path towards zero pollution and a healthier planet for us all.

Ekaterina Zaharieva

**Ekaterina Zaharieva, Commissioner for Startups, Research and Innovation**

# Editorial

The triple planetary crisis of climate change, pollution and biodiversity loss is all around us. With increasing frequencies of heatwaves and floods, continuing pollution of the air, land and sea, and declining populations of pollinators and birds, the three elements of the crisis are interconnected and our solutions must therefore be systemic and integrated. Reducing pollution is a critical part of the solution. It provides clear benefits to increasing the resilience of our ecosystems, economy and society, to supporting our efforts to adapt to climate change, and of course, to protecting our health.

Zero pollution forms an integral part of the European Green Deal agenda. Over recent years, additional legislation has been introduced to further reduce pollution overall, and to protect people and ecosystems from the impacts of pollution. It is critical that these measures are fully implemented and enforced across the EU, and that we have effective and timely monitoring systems in place to assess progress and identify gaps in knowledge and policy.

This is why this second edition of the Zero pollution monitoring and outlook report is such an important piece of work. It provides both an update to the first report, published in 2022, but also further insight into progress against the 2030 targets of the zero pollution action plan, and clearly shows the linkages between the health of our ecosystems and the health of people. The impacts of pollution on health and wellbeing are largely preventable, making calls for a One Health approach, with more integration between different policy areas, even more pertinent. This focus on prevention rather than cure will also result in a more resilient society.

Policy developments in the last decades have managed to abate pollution levels within the EU. However, there is now a growing push towards greater European autonomy, requiring increased mining and industrial activities here in the EU. It is important that the potential adverse environmental impacts from these increased activities are addressed in a way that ensures progress both towards zero pollution and increased strategic autonomy. The EU must shift to consumption patterns that deliver more value for citizens while reducing consumption in areas driving the greatest environmental harm: in other words, we must consume better, differently, and less.

This joint report, produced by the European Environment Agency and the Joint Research Centre of the European Commission, is an excellent example of the institutional collaboration required to bring the most comprehensive, up-to-date, and actionable data and knowledge into the policy debate. We look forward to further collaborations of this kind, as we continue to support Europe's work to reduce pollution across our region and beyond.

**Leena Ylä-Mononen, EEA Executive Director**

# Acknowledgements

This report was prepared jointly by the European Environment Agency (EEA) and the European Commission's Joint Research Centre (JRC). The EEA would like to acknowledge the collaboration with JRC colleagues and to thank its partners from the European Commission's Directorate-General for Environment (DG ENV) for their valuable input to the report.

In particular, the EEA would like to acknowledge the contributions of the following JRC colleagues: Andrea Chiorrini, Annarita Valenzano, Arwyn Jones, Alberto Pistocchi, Antonio Franco, Astrid Nedee, Bruna Grizzetti, Covadonga Astorga Llorens, Diana Simoes Vieira, Diego Macias Moy, Elisa Garcia-Gorriz, Elise Van Eynde, Esther Sanye Mengual, Enrico Pisoni, Felipe Yunta Mezquita, Francesco Galimberti, Georg Hanke, Jann Martinsohn, Karin Aschberger, Luis Francisco Ruiz-Orejon, Michael Bennett, Michael Olvedy, Panos Panagos, Piotr Wierzgala, Piotr Wojda, Philippe Thunis, Roberto Pasqualino, Susanne Belz, Stephanie Bopp and Vilma-Inkeri Kuuliala, and DG Environment colleagues Bettina Kretschmer and Joachim D'Eugenio.

Input from the European Topic Centre on Human Health and the Environment (ETC-HE) is also acknowledged.

The EEA also wishes to thank the European Agency for Safety and Health at Work (EU-OSHA), the European Chemicals Agency (ECHA), the European Environment Information and Observation Network (EIONET), the European Food Safety Authority (EFSA), the European Maritime Safety Agency (EMSA), the European Medicines Agency (EMA) and the Statistical Office of the European Communities (EUROSTAT) for their input.

# Executive summary

Pollution continues to pose a significant threat to ecosystems, the economy and public health. The European Green Deal (EGD), and particularly the zero pollution action plan (ZPAP), have modernised and expanded the European Union (EU)'s pollution-combatting regulatory framework. The second edition of the Zero pollution monitoring and outlook (ZPMO) report provides a comprehensive, up-to-date overview of pollution reduction efforts across different sectors. It outlines areas where the EU has made significant progress, as well as those which require further action. It builds on a wide range of data, offers key insights into the sources and impacts of pollution across the EU, and highlights both achievements and challenges as the EU works to meet the targets set out in the ZPAP.

As noted in the first Zero pollution monitoring assessment (ZPMA) in 2022, notable progress has been made in several areas including air quality, and reductions in pesticide and antimicrobial use. Nevertheless, agriculture, transport and waste remain important sources of pollution. The EU's excessive consumption of natural resources is leading to pollution at a scale that is unsustainable and its impacts exceed the planetary boundaries. This pollution also leads to significant impacts on third countries, due to imported goods. Furthermore, ongoing pressures on ecosystems highlight the urgency of reducing resource consumption and boosting circular economy initiatives while more rigorously enforcing existing environmental policies.

An analysis of the zero pollution targets reveals a mixed picture:

- **Target 1**, aimed at reducing health impacts from air pollution, is on track, highlighting successful regulatory improvements and emissions reductions that have led to significant decreases in premature deaths.

- There is limited progress under **Target 2**, which seeks a 30% reduction in the share of people chronically disturbed by transport noise; current efforts appear inadequate, particularly in urban areas, demanding more proactive noise management strategies at a national/local level.

- **Target 3**, which aims to reduce the impact of air pollution on ecosystems by 25%, seems unlikely to be met. Ongoing pollution, particularly from ammonia and nitrogen oxides, continues to threaten EU ecosystems.

- The reduction of nutrient losses by 50%, as outlined in **Target 4a**, is unlikely to succeed due to the persistent challenges of agricultural runoff and fertiliser use. While the EU is making progress to meet **Targets 4b and 4c**, which entail a 50% reduction in pesticide use and risk, it is important to note that the risk reduction might not solely be attributed to sustainable agricultural practices. This suggests the need to revise the indicators' methodology to ensure accurate assessment. **Target 4d** shows progress due to effective regulation and national measures which are currently likely to lead to a 50% reduction in the sales of antimicrobials for farmed animals and in aquaculture.

- **Target 5a**, aiming for a 50% reduction in plastic pollution, shows progress in reducing marine litter. **Target 5b**, which covers microplastics, is lagging behind, underscoring the need for enhanced regulations.

- Lastly, **Targets 6a and 6b** remain unlikely and off track, revealing an increase in waste generation. This highlights the necessity for ambitious waste prevention strategies and a transition toward a circular economy.

Full implementation and enforcement of environmental legislation is crucial to achieve the 2030 zero pollution targets. Notable among these are the revisions to the Industrial Emissions Directive (IED) and the introductions of the new Industrial Emissions Portal Regulation (IEPR), the Ambient Air Quality Directive (AAQD), the Urban Wastewater Treatment Directive (UWWTD), the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD) and the Mercury Regulation. Additionally, legislation under the Fit for 55 package is to play a key role in helping pollution reduction efforts alongside achieving climate goals. New legislation, such as the updated emission limits for motor vehicles (EURO 7) and the Nature Restoration Regulation (NRR), further reinforce the EU's zero pollution ambition. Current European Commission (EC) proposals are still in legislative progress, in particular for a revised surface and groundwater pollutants list, a Soil Monitoring and Resilience Directive (SML), further measures to assess and reduce the risk from chemicals, proposed measures under the circular economy action plan (CEAP) such as controls on plastic pellet losses to curb microplastic pollution. Improvements in waste prevention and management, as reflected in some recent legislation developments, will be also critical. To move forward towards zero pollution, the implementation of these new or revised laws will be essential.

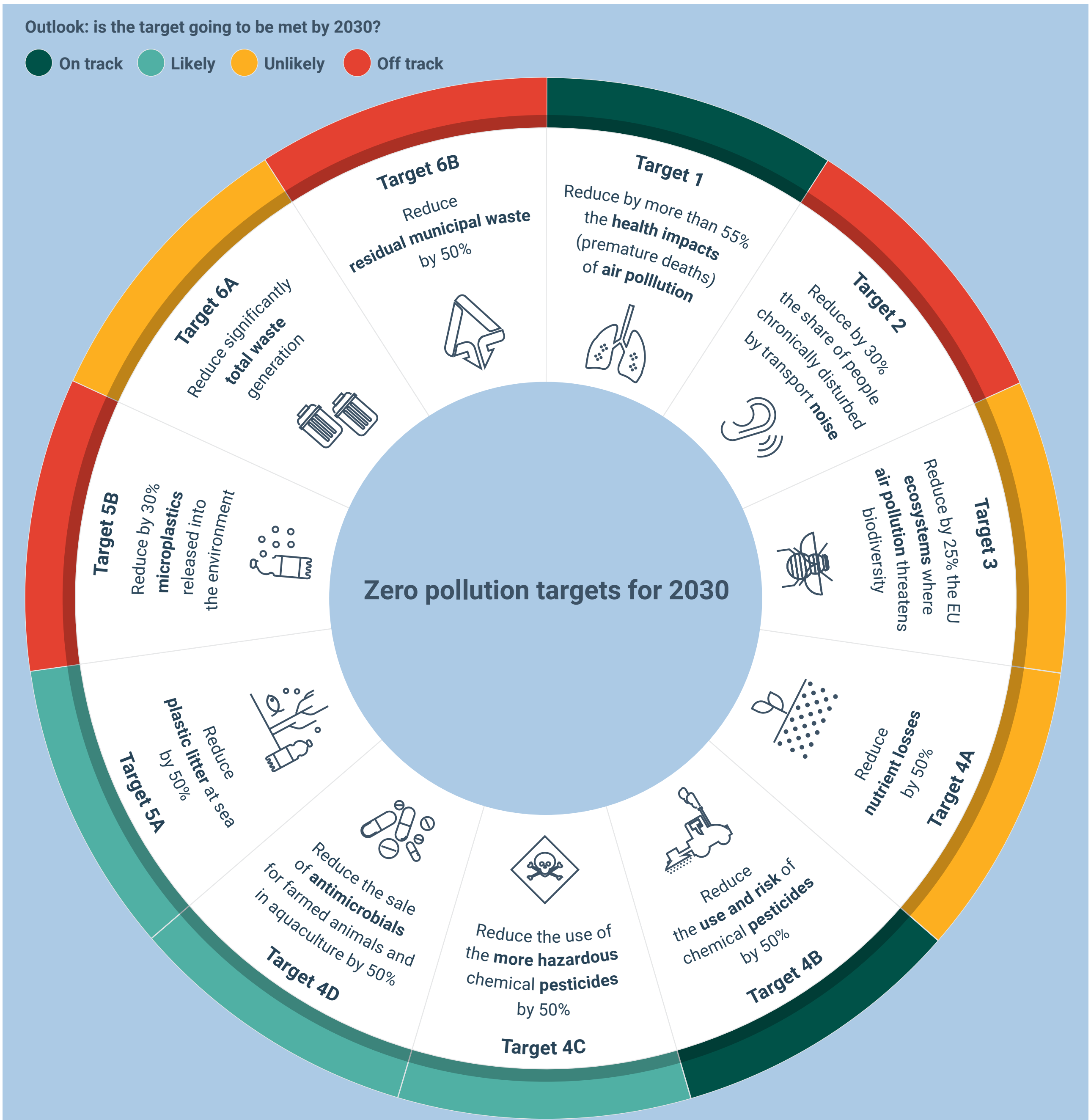
In some areas, however, additional action is needed. Insufficient action has been taken to address the EU's high levels of consumption, which are the primary driver of pollution stemming from the demand for food, housing, mobility and other necessities. The priorities set out in the political guidelines for the European Commission 2024-2029 ([1]) and the Competitivess Compass offer the possibility to address the identified opportunities and challenges. New efforts will align the zero pollution work with key initiatives including the announced Clean Industrial Deal, the vision for agriculture and food, the European water resilience strategy, the chemicals industry package, the ocean pact and the circular economy act. This will provide major opportunities to continue driving an agenda of clean, competitive and socially fair prosperity. And the deployment of clean technologies, products or services including nature-based solutions will help deliver a clean and competitive industry, sustainable consumption and production, climate resilience and preparedness as well as sustaining our quality of life by addressing environment-related health-risks.

Since the 2022 assessment, progress has been made in addressing data and knowledge gaps, including new assessments on microplastics, EU indicators framework for chemicals, a risk-based soil pesticide indicator and studies on the human health risks of pesticide exposure. Several legislative and non-legislative measures have also been taken or are under consideration to close these shortfalls in knowledge, yet challenges remain. Data and oversight gaps persist regarding compounds of concern in products placed on the market and some waste streams. Further research is needed into the health impacts of combined chemical exposures (the 'cocktail effect'), with research projects such as the Partnership for Assessment of Risk from Chemicals (PARC) helping to address such impacts and provide evidence for future policy measures. Threats to biodiversity from light pollution, soil contamination and underwater noise persist, although efforts are being made to address these through the new Kunming-Montreal Global Biodiversity Framework (KM GBF), the NRR and the SML. Nutrient losses remain difficult to measure due to the lack of a single, comprehensive indicator. Monitoring pesticide risks also remains challenging, although work started to develop science-based toxicity risk

([1]) https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf indicators for human health. For microplastics, gaps in monitoring remain and efforts to standardise methodologies across different media are ongoing. Improved data reporting, remote sensing and harmonised pollutant monitoring strategies are essential for better understanding and mitigating pollution impacts in the EU. Opportunities to benefit from digitalisation and innovation also need to be explored further, as these could contribute to less reporting burden, improved comparability and timeliness of the data.

Achieving the EU's interim and longer-term zero pollution targets by 2030 and 2050 respectively requires sustained, collaborative efforts across all sectors of the economy and society at both the EU and Member State level. While knowledge gaps persist, these should not be considered barriers to action, as there is clear evidence that measures to reduce pollution and its impacts need to be maintained or even increased. To accelerate progress, the EU and Member States must fully implement relevant legislative measures and strengthen pollution-related regulations while also enhancing cooperation among industries, public administrations and civil society. This is particularly important to ensure a just transition, addressing current inequalities in exposure and impact. A key focus will be the continued alignment of policies with the EGD objectives, ensuring that zero pollution principles are integrated into biodiversity, climate, economic, energy and industrial strategies. Moreover, boosting the synergies between zero pollution and competitiveness will be essential for Europe's sustainable prosperity.

**Figure ES.1. Zero pollution target analysis for 2025**




What progress has been made towards the targets?

| Target 1 | Target 2 | Target 3 | Target 4A | Target 4B | Target 4C | Target 4D | Target 5A | Target 5B | Target 6A | Target 6B |
|---|---|---|---|---|---|---|---|---|---|---|
| -45% | -2% | -13% | Stable | -46% | -25% | -28% | -29% | +7-9% | -0.5% | -1.5% |
| Baseline year: 2005 | Baseline year: 2017 | Baseline year: 2005 | Baseline year: 2012-2015 | Baseline year: 2015-2017 | Baseline year: 2015-2017 | Baseline year: 2018 | Baseline year: 2015 | Baseline year: 2016 | Baseline year: not defined* | Baseline year: not defined* |

Notes: Each target assessment has assumptions and limitations. For example, the co-benefits of implementing the newly adopted Nature Restoration Regulation remain unquantified for Target 3. The EU's extensive strategy and legislation on macro- and microplastic pollution — including the SUPD, WFD, PPWD, and MSFD — are expected to reduce plastic waste, with the new Packaging and Packaging Waste Directive making a significant contribution. Yet, such impacts are covered by Targets 5A and 6A and still difficult to quantify under Target 5B (see Figure 2.1, pages 14-19, for detailed explanations on the assessment of the 2030 progress and outlook).

*Although no baseline year is formally defined for Target 6A and 6B, the years 2010 and 2018 were selected, respectively, to allow assessment of progress. The plus (+) and minus (-) symbols indicate the increase and decrease, respectively, calculated for each indicator.

Source: EEA.

# 1 Introduction

Environmental pollution remains a great concern, despite the progress made so far. 78% of European residents are worried about the impact of harmful chemicals in everyday products on people's health and the environment (EC, 2024a). Air pollution remains the largest environmental health risk in Europe, with exposure to fine particulate matter and high nitrogen dioxide levels estimated to cause more than 250,000 premature deaths each year (EEA, 2024a) which represents however a 45% decrease compared to 2005. 'Forever chemicals' such as PFAS are increasingly found in drinking water. Furthermore, light and noise pollution as well as unsustainable resource consumption further exacerbate negative environmental impacts.

Pollution is a key driver of biodiversity loss and climate change, contributing to the 'triple planetary crisis' where each environmental threat can exacerbate the impact of the others. The Oder River disaster — a massive fish kill between Germany and Poland in the summer of 2022 — serves as a striking example of this interconnection, highlighting the need for integrated solutions to address these challenges.

Pollution can also lead to significant economic costs, including health expenses, remediation and treatment costs, regulatory compliance expenses as well as affecting public finances. Furthermore, pollution and related incidents can harm the reputation of businesses, cities, regions and countries, reducing consumer trust, affecting specific economic sectors and causing economic losses. Conversely, addressing pollution can drive innovation and investment in both clean technologies and sustainable practices, positively impacting competitiveness and economic growth. The costs associated with pollution and the benefits of combating it highlight the need for comprehensive action to provide effective solutions.

To achieve a clean and healthy planet, the ZPAP (EC, 2021a) has set key targets for 2030 to accelerate pollution reduction.

## Box 1.1

**The zero pollution targets for 2030**

To steer the EU towards the 2050 vision of a clean and healthy planet for all, this action plan sets key 2030 targets to speed up pollution reduction. By 2030, the EU should reduce:

- by more than 55% the health impacts (premature deaths) of air pollution;
- by 30% the share of people chronically disturbed by transport noise;
- by 25% the EU ecosystems where air pollution threatens biodiversity;
- by 50% nutrient losses, the use and risk of chemical pesticides, the use of the more hazardous ones, and the sale of antimicrobials for farmed animals and in aquaculture;
- by 50% plastic litter at sea and by 30% microplastics released into the environment; and
- significantly reduce total waste generation and reduce by 50% residual municipal waste.

The longer-term objective of the plan is to reach zero pollution by 2050. By that year, air, soil and water pollution should be reduced to levels no longer considered harmful to health and natural ecosystems, thereby creating a toxic-free environment.

Both the ZPAP and the wider EGD have modernised the robust EU regulatory framework to address pollution. Key legislative actions will play a significant role in achieving the 2030 zero pollution targets — in particular the revision of the:

- Industrial Emissions Directive and the new Industrial Emissions Portal Regulation
- Ambient Air Quality Directive
- Urban Wastewater Treatment Directive
- Mercury Regulation
- Legislation within the Fit for 55 package.

Additionally, new legislation including EURO 7 and the NRR — or various proposals, like those for a revised surface and groundwater pollution list, an SML and the control of plastic pellet losses — reflect the EU's commitment to zero pollution. Overall, more than 90% of the zero pollution actions and flagships have been delivered by 2024 (EC, 2024b).

### Looking ahead, the focus will shift to implementation

The 2024 political guidelines of the President of the European Commission, Ursula von der Leyen, make it clear that "we must and will stay the course on the goals set out in the European Green Deal'. This underscores the need to sustain our efforts in advancing zero pollution initiatives and aligning with key legislation for the Commission mandate 2025-2029 and the Competitiveness Compass. These include the clean industrial deal, the vision for food and agriculture, the European water resilience strategy, the ocean pact and the circular economy act.

The deployment of clean products, technologies and services through the IED demonstrates the EU's more than 20-year history of environmental and industrial leadership. Thanks to the IED, large combustion plants (LCPs) now emit seven times less air pollutants than 20 years ago. Despite progress in reducing air pollution, fine particulate matter emissions from manufacturing stalled between 2018 and 2020, suggesting the need for further innovation to move towards a zero pollution industry in the EU (EC, 2024c).

The recently adopted amendment to the IED is expected to accelerate the uptake of zero pollution innovation and create a level playing field for highly polluting sectors.

The review of the ZPAP, the chemical industry package and the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) revision, along with actions on per-and polyfluoroalkyl substances (PFAS), will be the headline initiatives towards zero pollution. These efforts will continue to align with biodiversity protection and the drive towards carbon neutrality, with the circular economy a key enabler.

To track progress towards the ZPAP's targets, it is important to have robust monitoring and outlook mechanisms in place. The European Environment Agency (EEA) is responsible for assessing progress towards zero pollution objectives through its continuous monitoring and reporting on the state of Europe's environment. This monitoring factors in the policy measures implemented, identifying the 'distance to target' for each objective and highlighting both the successes in achieving the goals and the risks of not reaching them. The EEA assessment is based on data coming from a broad range of EU data sources, which are presented as a set of indicators and signals in the Zero pollution monitoring dashboard.

## Box 1.2

**Towards integrated environmental monitoring**

The ZPMO is part of wider efforts to integrate monitoring and outlook frameworks for environmental policy priorities in the context of the Eighth Environment Action Programme (EU, 2022a). The 8th EAP monitoring framework (EC, 2022a) includes three indicators which measure progress on some zero pollution targets: air quality, premature deaths due to $PM_{2.5}$ exposure, nitrates in groundwater (linked to nutrient reduction) and waste generation. The aim of this zero pollution report is to complement the annual 8th EAP monitoring by deepening the understanding of progress and perspectives on achieving the zero pollution ambition, one of the priority objectives of the 8th EAP and the EGD. Similar monitoring frameworks exist for biodiversity (EC, 2024d), the circular economy (EC, 2023a; EC, 2024e,) and climate change (EU, 2018).

Moreover, the ZPMO benefits from the EU indicator framework for chemicals and the European environment and health atlas. These three products together build a strong evidence base to support and assess progress towards the zero pollution ambition. While all these initiatives have been closely coordinated and have created many synergies, there is ongoing effort to further improve their policy relevance, coherence and complementarity.

These frameworks are also supported by many regulatory and environmental monitoring programmes, ensuring that data are findable, accessible, interoperable and reusable (FAIR) and that indicators can be easily updated. For example, the Information Platform for Chemical Monitoring (IPCHEM) is the EC's reference access point for searching, accessing and retrieving chemical occurrence data collected and managed in Europe.

The EC's Joint Research Centre (JRC) is responsible for delivering the zero pollution outlook component of this report. It seeks to quantitatively assess the effectiveness and expected impacts of existing or planned pollution-reducing measures. It provides projections for future years by analysing various scenarios, including a business as usual (BAU) scenario with no (additional) intervention, as well as scenarios involving different levels of ambition, as appropriate. These scenarios consider the partial or full adoption of operational and technical measures to reduce pollution. The feasibility of achieving the 2030 and 2050 zero pollution targets is evaluated, steering future policy initiatives towards those targets. The conclusions of the outlook also build on results published in peer-reviewed articles and technical JRC reports.

This second edition — which combines the relevant parts of the ZPMO into a single document — offers comprehensive information about pollution sources stemming from production and consumption, as well as pollution impacts on ecosystems and human health, addressing key knowledge gaps and exploring next steps. It serves as a crucial tool for assessing progress; identifying trends and hotspots; providing early warnings; raising awareness; informing policy decisions; and facilitating international cooperation in addressing pollution and environmental challenges.

# 2 Zero pollution target analysis — past trends, current status and future outlook

This section presents progress towards zero pollution targets. The 'distance to target' (an assessment of the likelihood of meeting the target based on the current status and recent trends) and the 'outlook' (an assessment of the likelihood of meeting the 2030 targets and the long-term 2050 vision) are provided for each specific target. An element of expert judgement is also used where there are uncertainties in the available evidence. The distance to target and outlook are categorised in Figure 2.1.

**Figure 2.1 Status categorisation of zero pollution targets and outlooks**

| | | |
|---|---|---|
| ● | On track | The current status and past trend/models/prospects indicate that the EU is on track to meet the target by 2030. |
| ● | Likely | The current status and past trend/models/prospects indicate that the EU is likely on track to meet the target by 2030. |
| ● | Unlikely | The current status and past trend/models/prospects indicate that the EU is unlikely on track to meet the target by 2030. |
| ● | Off track | The current status and past trend/models/prospects indicate that the EU is off track to meet the target by 2030. |
| ? | Unclear | Distance to target/outlook cannot be determined (e.g. there is insufficient data/evidence, no correlation between indicator and selected objective). |

The assessment of both the 'distance to target' and the 'outlook' for each indicator is based on the best available data, models and expert judgement. However, due to potential gaps in data, variations in trends and the complexity of environmental processes, these assessments may be subject to change. As a result, the categorisation of progress should be interpreted with caution, particularly where uncertainties or limitations in evidence exist.

**Target 1: Reduce by more than 55% the health impact (premature deaths) of air pollution**

| Indicator name | Current position/trend | Distance to target | 2030 outlook | Analysis |
|---|---|---|---|---|
| Premature deaths due to exposure to fine particulate matter in Europe | Between 2005 and 2022, the number of premature deaths in the EU attributable to $PM_{2.5}$ fell by 45% — with no change compared to 2020, which also showed a 45% reduction. | The status and past trend indicate that the EU is on track to meet the target by 2030. If the number of premature deaths continues to fall at the rate seen between 2005 and 2022 and the EU policies on air, climate and energy are adequately implemented, the 55% target can be met by 2030. | On track: The 4th Clean Air Outlook indicates a decline in premature deaths by 62-68% in 2030 compared to 2005 across the various modelled scenarios. This trend is consistent with the 66% prediction from the 2022 outlook, highlighting the positive effects of air quality improvements resulting from clean air, climate mitigation and energy policies, assuming their full implementation. | On track ● |

| Target 2: Reduce by 30% the share of people chronically disturbed by transport noise | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Exposure of Europe's population to environmental noise | A slight decrease (2%) in the population affected by harmful noise levels is estimated between 2017 and 2022. | The status and past trend indicate that the EU is currently off track to meet the target by 2030. Despite the slight decrease since 2017, 2022 data still show many people living in areas with transport noise levels considered harmful to health. Various policies aimed at addressing transport-related noise have not resulted in significant overall reductions. | Off track: Projections suggest that the number of people highly annoyed by transportation noise could decrease by 2% to 23% by 2030, in a conservative and optimistic scenario respectively. These findings align with earlier estimates from 2022, which predicted a 19% reduction. This means that without additional measures, such as regulatory or legislative changes, achieving a reduction of at least 30% in the number of people chronically disturbed by transport noise levels by 2030 will not be possible. | Off track |

| Target 3: Reduce by 25% the EU ecosystems where air pollution threatens biodiversity | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Eutrophication caused by atmospheric nitrogen deposition in Europe | Between 2005 and 2022, the total area where nitrogen deposition exceeded the critical loads for eutrophication fell by 13%, with a slight improvement compared to the reduction of 12% observed between 2005 and 2020. | The status and past trend indicate that the EU is unlikely to meet the target by 2030. While there has been improvement over time, the current rate is not enough to reach the target by 2030. | Unlikely: The 4th Clean Air Outlook indicates that the area of ecosystems affected by eutrophication due to nitrogen deposition will reduce by 19% by 2030 with baseline policies only (implementing the Nature Restoration Regulation may bring additional benefits). This is consistent with the results of the 3rd evaluation in 2022, indicating no further progress towards the targeted 25% reduction compared to 2005. Achieving the target would require the implementation of all technical measures ('maximum technically feasible reduction'), potentially resulting in a 31% reduction by 2030 or at least of some additional measures at Member State level to reduce ammonia emissions (see the 4th Clean Air Outlook for details). | Unlikely |

| Target 4a: Reduce nutrient losses by 50% ([2]) | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Nitrate in groundwater in Europe | The average nitrate concentration in EU groundwaters did not change significantly from 2000 to 2022 — oscillating around 21 mg $NO_3$/l. | The status and past trend indicate that the EU is unlikely to meet the target by 2030. Results from a high ambition model scenario show that potential nutrient load reductions are substantial, but still below the 2030 target. | Unlikely: Nutrient reduction targets will not be met by 2030 under the current policy, according to a 2023 Integrated Nutrient Management study (Grizzetti et al., 2023). Agriculture will remain a major source of nutrient losses to the air and water in several European regions. | Unlikely |
| Gross nutrient balance | Data not available yet | Not assessed yet | | |

| Target 4b: Reduce the use and risk of chemical pesticides by 50% ([3]) | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| EU trends in the use and risk of chemical pesticides | In the first five years (2018 to 2022), there was an overall decrease of 46% in the use and risk of chemical pesticides from the baseline period of 2015-2017; the values were 14% in 2019 and 27% in 2020. | The status and past trend indicate that the EU is on track to meet the target by 2030. If the rate of improvement is maintained, the target could be met. | On track: A 46% reduction in pesticide use and risk was observed between the baseline period 2015-2017 and the year 2022. Due to the complexity of factors influencing this trend, predicting its future evolution is challenging. One potential contributor to this reduction is the withdrawal of active substances. The availability of alternative pesticides may thus impact future reductions. However, the role of sustainable agricultural practices in risk reduction is currently unclear and requires further investigation. | On track |

([2]) The target analysis has been conducted using the headline indicators; however, other indicators are available which provide additional context to this target analysis and further highlight the complexity in addressing the impacts of nutrients. The indicators 'Nutrients in freshwater in Europe', 'Nutrients in transitional, coastal and marine waters in Europe' and 'Ammonia emissions from agriculture and other sources' need to be revisited to gain a better understanding of nutrient releases.

([3]) Under the Farm to For Strategy and the CAP Strategic Plans, the Harmonised Risk Indicators (HRIs) have been identified as reference for achieving the 50% reduction target (see COM(2020) 846, Annex 1) but these indicators have significant shortcomings. The Commission is committed to developing more sophisticated indicators in future, such as improved weightings that take hazard properties into account in a more granular way or by using EU-level data on pesticide usage when it becomes available. An example of such an improvement is the new risk indicator assessing the toxicity of pesticide residues in soil from samples collected under the LUCAS Soil Pesticide survey coordinated by JRC. When interpreting the current monitoring and outlook findings, it is important to underline that the overall volume of active substances used in pesticides has increased since 2011, and the decrease in the use and risk indicator has not (yet) resulted in improvement on environmental quality (see the indicators on 'Pesticides in rivers, lakes and groundwater', and the signals on the 'Ecological risk of pesticides in EU soils' and 'Pesticides impacts on human health').

| Target 4c: Reduce the use of the more hazardous chemical pesticides by 50% (3) | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend (4)** | **Distance to target** | **2030 outlook** | **Analysis** |
| EU trends in the use of more hazardous chemical pesticides | In the first five years (2018 to 2022), there was an overall decrease of 25% in the use of more hazardous pesticides from the baseline period of 2015-2017. In 2020, the reduction was 26%, an only slightly higher percentage pointing to a stagnation in the trend. | The status and past trend indicate that the EU is likely to meet the target by 2030. If the rate of improvement is maintained, the target could be met. | Likely: The trend analysis demonstrates a 25% reduction in the use of the more hazardous chemical pesticides between the baseline period 2015-2017 and 2022, suggesting the target may be reached by 2030. Lower use and withdrawal of more hazardous pesticides are major reasons for this. However, challenges to continuing this trend include the finding of lower-risk alternatives and the potential renewal of more hazardous substances. It is still possible to achieve the target but to keep making progress, sustainable agricultural practices and safer alternatives need to be prioritised while high-risk pesticides are monitored and regulated. | Likely |

| Target 4d: Reduce the sale of antimicrobials for farmed animals and in aquaculture by 50% | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Antimicrobial consumption in food-producing animals in the EU | In 2022, the sales of veterinary antimicrobials for food-producing animals in the EU fell by 28% compared to 2018. This is due to the efforts of Member States and the implementation of policies under related regulations. | The status and past trend indicate that the EU is likely to meet the target by 2030. The reduction achieved so far is more than half of the 2030 50% reduction target. Nevertheless, Member States will have to continue acting to further cut consumption of antimicrobials for farmed animals and aquaculture by another 22%. | Not available | Likely |

(4) Risk for the whole period is recalculated according to the methodology of HRI, hence risk reductions published in the first ZPMA report might appear different.

| Target 5a: Reduce plastic litter at sea by 50% | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| EU coastline macro litter trends | Beach litter decreased by 29% between 2015 and 2021. This stems from new data that have been assessed for the first time (JRC, 2024). | The status and past trend indicate that the EU is likely to meet the target by 2030. The 29% reduction in 6 years is a significant step towards meeting the 2030 target. | Likely: Significant reductions in macro litter pollution on EU beaches — up to 42%, potentially — can be achieved by 2030 through ambitious measures. The ZPAP target can be achieved in 52% of Member State beaches. | Likely |

| Target 5b: Reduce by 30% microplastics released into the environment | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Microplastic releases to the environment | There was a slight increase (approximately 7-9%) in microplastic releases between 2016-2022. This stems from new data that have been assessed for the first time (ETC/HE 2024a). This estimated increase has a high level of uncertainty; however, it was clear that there is no evidence to suggest a decrease in emissions. | The status and past trend indicate that the EU is currently off track to meet the target by 2030. There has been no progress in reducing microplastic releases. | Off track: A total reduction of 7% could be achieved by 2030, assuming the proposed 'Pellet Regulation' (EC,2023b) is adopted without major changes and in combination with the REACH restriction. It should be noted that these estimates have a high level of uncertainty. | Off track |

| Target 6a: Reduce significantly total waste generation | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Waste generation in Europe | Total waste generation continued increasing in the EU, apart from a temporary reduction close to 8% between 2018 and 2020, with a slight net reduction (0.5%) between 2010 and 2022. Waste generation excluding major mineral wastes — which are generally less concerning — increased by 3.3% between 2010 and 2022. | The status and past trend indicate that the EU is unlikely to meet the target by 2030. Waste generation follows changes in the EU Gross Domestic Product (GDP) and it has continued increasing, albeit at a slower pace than the economy. The EU is not on track for meeting the zero pollution target of significantly reducing waste generation. Only very ambitious waste prevention measures could get it back on track. | Unlikely: Waste generation follows changes in the EU GDP and it is therefore not expected to decrease without very ambitious prevention measures. | Unlikely |

| Target 6b: Reduce residual municipal waste by 50% | | | | |
|---|---|---|---|---|
| **Indicator name** | **Current position/trend** | **Distance to target** | **2030 outlook** | **Analysis** |
| Reaching 2030 residual municipal waste target | The trend had been decreasing but has reached a plateau since 2015: with a 16% decrease between 2004 and 2022, the decrease between 2018 and 2022 has been slight (-1.5%). | The status and past trend indicate that the EU is off track to meet the target by 2030. Despite efforts to increase municipal waste recycling, the EU is not on track to meet the zero pollution target of halving residual municipal waste by 2030. This ambition will not be met without intensive efforts to prevent waste generation. | Off track: The projected increase in municipal waste prevents the EU from achieving a 50% reduction in residual waste by 2030. Meeting this target would require significant efforts to prevent waste generation and achieve recycling rates higher than current EU objectives. It is unlikely that the target will be achieved, even if municipal waste recycling rates increase considerably. | Off track |

# 3 Pollution from production and consumption

## 3.1 Pollution from resource extraction

**Key messages**

- Emissions of major pollutants to air (e.g. particulate matter and nitrous oxides) from European extractive activities decreased at a slower pace between 2010 and 2022 than in previous decades, with an increase for all pollutants between 2020 and 2022.
- Heavy metal emissions to air remained essentially stable between 2010 and 2020, but increased between 2021 and 2022.
- EU initiatives to boost domestic material extraction — like the critical raw materials (CRM) act — might increase pollution in Europe. The revised Industrial Emissions Directive, now including the mining of certain metal ores, is expected to ensure good environmental standards within the sector.
- Further measures are required to monitor and minimise the pressures of resource extraction on soil and water quality, as well as to remediate contaminated soils, with the proposed soil monitoring law.
- Actions strengthening the circular economy are needed to help reduce demand for virgin materials and related pollution impacts, and contribute to the EU's strategic autonomy.

### *3.1.1 Introduction*

Extractive activities provide the primary raw materials that are essential for manufacturing processes and energy production. As described in the first ZPMA (EEA, 2022a), the extraction phase of the production chain generally accounts for a significant share of a product's environmental impacts. Globally, more than 40% of pollution impacts (based on particulate matter impacts on human health) derive from the extraction and first processing of material resources (metals, non-metallic minerals, fossil fuels and biomass, the latter also covering agricultural production) (UNEP, 2024). Pollutants released from resource extraction activities include major pollutants such as heavy metals and chemicals.

### *3.1.2 Emissions from extractive industries*

Between 2010 and 2022, the EU saw a slower reduction in major air pollutants (non-methane volatile organic compounds, sulphur oxides, particulate matter and nitrogen oxides) from extractive activities than in previous decades (see indicator

'Emissions of major pollutants into the air by extractive industries'). Improved air pollution control measures led to decreased emissions, even when resource extraction remained stable or even increased, particularly in metal production. Additionally, reduced emissions from oil and gas may be attributed to declining fossil fuel extraction. Between 2020 and 2022, the declining trend in all major pollutant emission reductions reversed.

EU data indicate a rather stable trend in heavy metal emissions to the air from extractive activities, with slight increases observed between 2021 and 2022 (see indicator 'Heavy metal emissions to air by extractive industries').

Recent data from the land use and coverage area frame survey (LUCAS) (see Section 5.4 Soil pollution and ecosystems) identify mining activities as relevant sources of metal contamination. Despite this, data on the sector's impacts on water and soil, as well as actions on soil remediation, remain limited as highlighted in the ZPMA (EEA, 2022a). Complete inventories of contaminated sites as well as up-to-date information on soil destruction and remediation are lacking at the EU level (EEA, 2024b).

### *3.1.3 Increasing demand for materials (outlook)*

The global demand for materials is expected to increase greatly in the coming decades. UNEP (2024) estimates a 60% increase between 2020 and 2060, with a continuous increase until 2050. The stable trend observed over the last 10 years in the EU's demand for materials suggests that it is not likely to significantly reduce its material footprint in the coming decade (EEA, 2023a).

When considering CRMs, extraction is projected to increase significantly both in the EU (EU, 2024a; Carrara et al., 2023) and globally in the coming years, potentially leading to amplified pollution if mining activities are not carefully managed. There are currently no estimates of the potential pollution impacts within the EU, whether considering emissions to air or the pollution of soil and water from extraction activities and from the management of extractive waste. The expected negative impacts need to be assessed together with the environmental benefits of using these CRMs, particularly in the context of the energy transition.

### *3.1.4 Recent policy developments*

Some policy developments have addressed the extractive sector since the publication of the ZPMA (EEA, 2022a). The Critical Raw Materials (CRMs) Act (EU, 2024a) aims to ensure a secure supply of CRMs to EU industries. It establishes targets for strategic raw materials ([5]), including that at least 10% of the extraction and 40% of the processing of the EU's material consumption should be met within the EU by 2030. The CRMs Act also aims to speed up permitting processes for CRMs, develop national exploration programmes and expand partnerships with CRMs-producing third countries. This means that more extraction is expected both in the EU and partner countries. The CRMs Act states that this should be done in an environmentally and socially sustainable manner ([6]). The revised IED (EU, 2024b) is expected to help streamline and accelerate the permit-granting process of the CRMs Act and it has also expanded its scope to include the extractive sector, specifically the extraction and treatment of certain metal ores ([7]). This means that these mining activities will have to operate according to the Best Available Techniques (BATs),

([5]) A subset of CRMs, as listed in Annex I, Section 1 of the CRMs Act.
([6]) This will be considered for strategic projects receiving support and those placing CRMs on the EU market will be obliged to make available an environmental footprint declaration — whenever the Commission has adopted calculation and verification rules.
([7]) Bauxite, chromium, cobalt, copper, gold, iron, lead, lithium, manganese, nickel, palladium, platinum, tin, tungsten and zinc.

i.e. binding minimum environmental requirements. The development of the BATs and the BAT Reference Document (BREF) for these activities started in 2024.

Interest in mining in the deep sea, which is controlled by the International Seabed Authority (ISA), continues around the world, including in EU neighbouring countries. While European countries have sponsored deep-sea mining contracts with ISA, the EU continues to advocate for the precautionary principle and promotes a moratorium on deep-sea mining until there is robust evidence on its environmental impacts. The European Academies' Science Advisory Council (2023) has highlighted major knowledge gaps regarding such impacts ([8]) and contests the argument that deep-sea mining is essential to meet the material needs of the green transition.

In 2023, the EC proposed a law to establish an EU soil monitoring framework. It aims to improve the monitoring of soil destruction and both diffuse and local soil contamination and facilitate the detection and management of sites with ongoing or historic polluting activities.

Scaling up the circular economy could significantly help address the current climate and environmental crises while also fostering competitiveness and resilience within the EU. Circular economy practices prolong the lifespan of materials and products, reducing the need for virgin materials and minimising waste generation (EEA, 2023a), thereby also reducing pollution from extraction and processing. This approach is in line with the highest level of the Zero pollution hierarchy, which prioritises pollution prevention. The CRMs Act (see also above) sets a target that at least 25% of the EU's annual consumption of strategic raw materials comes from recycling by 2030, while also aiming to reduce the demand for virgin materials and increase the EU's open strategic autonomy and resilience. Currently, this target is met for some materials (e.g. copper and tungsten), while other materials (e.g. lithium and rare earth elements) almost exclusively come from virgin extraction (EC, 2023c). In this context, the 2024-2029 political guidelines of EC President von der Leyen underline the importance of the circular economy to create a market demand for secondary materials and a single market for waste, notably in relation to CRMs.

In addition, the 2023 regulation proposal for End-of-Life vehicles (EC, 2023d) intends to increase the circularity of the automotive industry, one of the most resource-intensive industries in the EU; at the same time, the new Regulation on batteries and waste batteries (EU, 2023a) aims to ensure the sustainable sourcing of the materials used in battery production and introduce targets for recycled content. Scaling up circular economy strategies requires other strategies than just recycling, such as refuse, reuse, repair, refurbish and remanufacture, which offer great benefits in reducing overall material demand (EEA, 2023).

### 3.2 Pollution from industrial production

#### Key messages

- Industrial air and water emissions decreased gradually between 2010-2022, with an increase in 2021 linked to the post-COVID-19 pandemic economic recovery.
- Industrial air pollution's external costs totalled EUR 2,684 billion between 2012 and 2021. Over the same period, a nearly 33% decrease in annual external costs was observed, driven mainly by decreases in air pollution from the energy sector.

([8]) On ecosystem structure and function, species present, how they interact and their tolerances and resilience.

- The revised IED contains stronger requirements for chemicals management and circular economy actions to boost industry's environmental performance. It aims to address the need for deep industrial transformation and innovative solutions to reduce environmental impacts at source, rather than the current and more traditional end-of-pipe approach.
- New chemicals policies and further implementation of existing ones are expected to reduce the use of hazardous substances by both steering innovation towards 'safe and sustainable by design' (SSbD) of chemicals and materials, and by further restrictions on current uses.
- Effective implementation of current policies is essential for the success of the new and revised environmental legislation for industry. This will require the efficient application of innovative technologies, swift targeting of emerging pollutants and EU action to support Member States in achieving a common playing field for industries in their capacity to tackle environmental impacts.

### *3.2.1 Introduction*

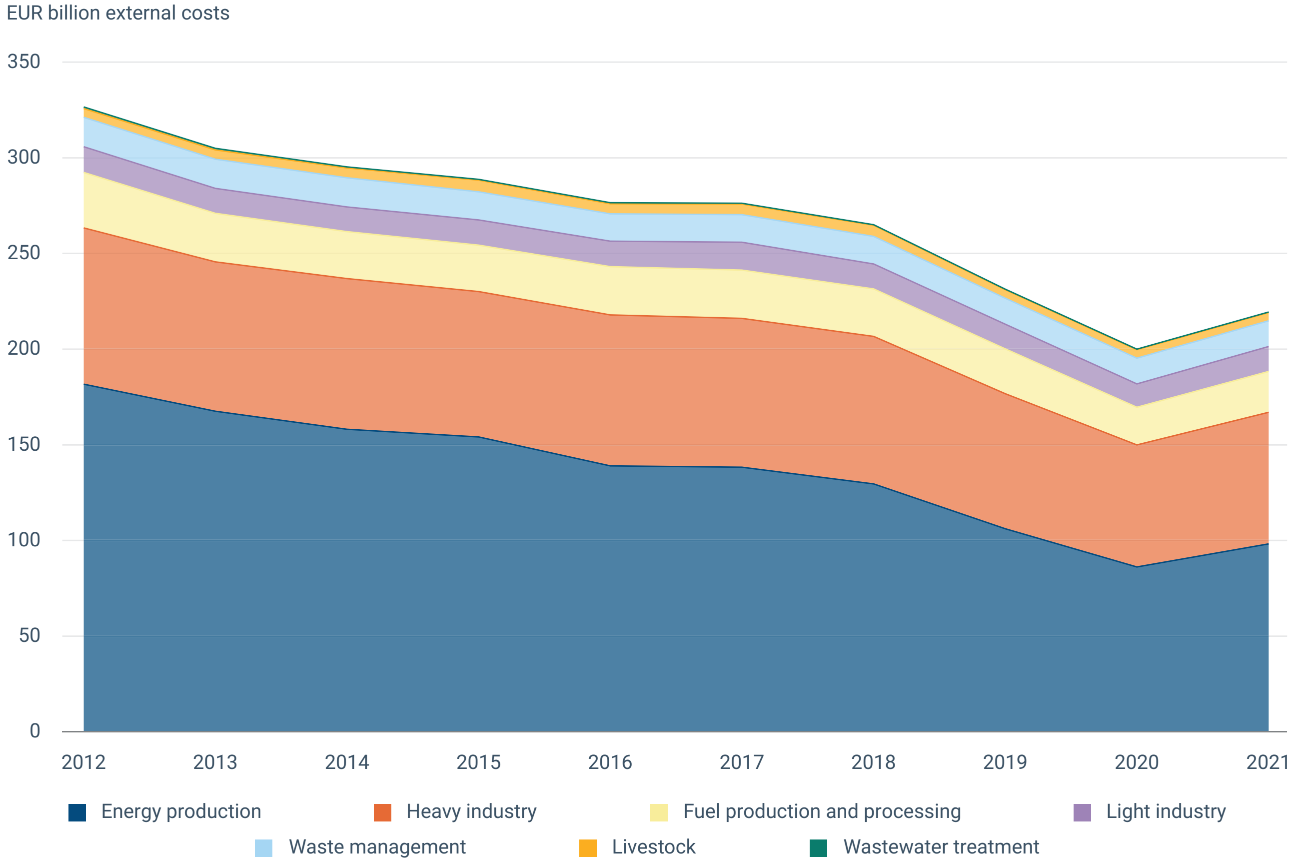
The manufacture of goods occurs in large and small factories across the EU. This generates goods, employment and tax revenue, but also produces emissions and other pressures on the environment — such as air pollution, changing land use and increased water demand. The first ZPMA in 2022 (EEA, 2022a) included a detailed overview of the situation in production systems.

### *3.2.2 Emissions from industry*

Industrial air and water emissions decreased gradually between 2010 and 2022 as presented in the indicators 'Industrial pollutant releases into air in Europe' and 'Industrial pollutant releases into water in Europe'. During this period, there was a dip in emissions to air until 2020 and an increase in 2021 linked to economic recovery after the COVID-19 pandemic. Emissions data reported for 2022 confirm the overall declining trend seen between 2010 and 2020. This decrease can be seen in all pollutants covered by these indicators (non-methane volatile organic compounds (NMVOCs), NOx, heavy metals, course particulate matter ($PM_{10}$), SOx, total P, total N). Heavy metals (reported in both air and water emissions) have also seen a declining trend, but with fluctuations over the last decade.

The new indicator on air pollution externalities produced for the current assessment (Figure 3.1) (see indicator 'External cost of industrial air emissions') links emissions to their impact on health (mainly) and the environment. These 'external costs' essentially represent the economic cost associated with the negative impacts of industrial air pollution which are not borne by industry. The indicator shows that the external costs of industrial air pollution amounted to a total of EUR 2,684 billion between 2012 and 2021, decreasing by 33% over this period. The energy sector was responsible for the biggest decrease in absolute terms (80% of the overall decrease), followed by heavy industry, fuel production, and the processing and light industry. This large decrease in emissions from the energy sector can be attributed to the shift from coal to natural gas and renewables in the power sector, driven by climate and environmental policies (see Box 3.1 below for a dedicated analysis on LCPs).

**Figure 3.1** **Total external costs of industrial air pollution from European Pollutant Release and Transfer Register (E-PRTR) facilities — total per sector, 2012-2021**




**Notes:** For the main air pollutants, the health impacts have been quantified using the VOLY ([9]). For livestock emissions, it is important to consider that cattle farming, which is the biggest source of methane and the second biggest source of ammonia emissions to air from agriculture, does not report to E-PRTR and consequently, is not reported in the European Industrial Emissions Portal, which is the source of these data. Coverage here corresponds to air emissions from facilities undertaking intensive rearing of poultry (with 40,000 places and above), pigs (with 2,000 places and above, for pigs over 30 kg) and sows (with 750 places). For wastewater treatment, most environmental pollution is due to water emissions, while this assessment refers only to air emissions. Euro price base: 2021. Data gaps: Czechia (2021), Malta (2020-2021), Lithuania (2020-2021) and Slovakia (2018-2021). These data have been projected using the latest reported year for this summary at sector level.

**Source:** Based on EEA, 2024c.

It is argued that the adoption of circular strategies in four key sectors — aluminium, cement, plastics and steel — could decrease greenhouse gas (GHG) emissions from key industry materials by 40% by 2050 (Ellen MacArthur Foundation, 2019; EEA, 2023a). A key enabler for this adoption will be the availability of recycled materials, as sustainable feedstocks for industry will be critical (EEA, 2023a). The EC estimates that by 2050, the revised IED (see Box 3.1) will deliver up to 40% reductions in emissions of the main air pollutants from industrial activities under its scope. Avoiding future lock-ins in energy-intensive industries, i.e. investments in systems with high energy requirements, is also key (UNEP, 2024).

([9]) Damage to health caused by the main air pollutants shown as 'value of a life year' (VOLY): An estimate of damage costs based on the potential years of life lost which accounts for the age at which deaths occur (with a higher weighting for younger people). There are other methods to quantify mortality, such as the value of a statistical life (VSL) which leads to different costs per tonne.

## Box 3.1

**Large combustion plants: a story of environmental policy success**

Regulated since the 1980s initially due to their high contribution to acidification, large combustion plants (LCPs) are one of the industrial activities with the most strategic relevance in the EU and for which air emissions have been tracked for the longest time. They have been a major source of greenhouse gases and air pollution, especially $SO_2$, NOx and dust but also heavy metals, including mercury.

To tackle the environmental impacts caused by LCPs, the EU has used an EU-wide policy framework coherent with the internal energy market. The influence of this framework is clearly visible in the LCP emission trends across Member States, in particular for $SO_2$ emissions.

This decrease relates to improved abatement technologies coupled with the decreasing use of coal in the sector, which has been replaced by natural gas and renewable energy sources.

A significant part of these improvements is driven by environmental and climate legislation, while other factors such as economic aspects played a part.

Whereas before 2004 there were clear differences between (groups of) Member States in terms of environmental performance, now all countries are able to perform at very similar levels, illustrating the effect on the level playing field.

Despite the improvements, LCPs continue to be one of the main sources of air pollution in the EU and are still responsible for 45% of the total external costs of industrial air pollution in 2021. The extent of these external costs caused by the sector that year can be seen in the map of the top 100 most damaging LCPs. Innovation, improved implementation and monitoring will be key to a transition to a cleaner power sector.

The recently revised Industrial Emissions Directive is a significant step in this direction by requiring more ambitious emission limit values based on best available techniques and placing more emphasis on innovation in the establishment of permit conditions for LCPs.

With more easily accessible data on environmental performance (see LCP tool), the Commission further investigates the evolution in compliance of the most polluting LCPs with stricter requirements, which is expected to result in further emission reductions.

In addition to this, the EEA is working on the use of other tools, including satellite imagery, to assess and validate emissions from LCPs. The availability of data on LCPs, and new data visualisation and satellite imagery tools, will lead to a simplification of the assessment of environmental performance data (see signal 'Progress in reducing pollution from large combustion plants').

### 3.2.3 Recent policy developments

Directive (EU) 2024/1785 (EU,2024b)(which revises the IED (2010/75 EU), now amended as the Industrial and Livestock Rearing Emissions Directive (IED 2.0), and the new Industrial Emissions Portal Regulation (IEPR) (Regulation (EU) 2024/1244) (EU, 2024c) aim to contribute to the better protection of human health and the environment, more innovative and transformative industrial changes, and more comprehensive and transparent industry reporting (EC, 2024f). Among other requirements, operators under the IED 2.0 will be required to ensure that the 'strictest achievable emission limit values' (ELVs) are met, considering cross-media effects. In view of boosting innovation, the Directive announces the creation of the Innovation Centre for Industrial Transformation and Emissions (INCITE)(EC,2024g), where operators will be required to have indicative transformation plans for each installation. Energy, resource and water efficiency will be strengthened by the inclusion of Best Available Techniques associated environmental performance levels (BAT-AEPLs) in the BAT conclusions. Based on modelling results from the EC, the new IED is expected to deliver up to 40% further reductions in the emission of the main air pollutants from industrial activities under its scope by 2050 ([10]).

On the reporting side, the European Industrial Emissions Portal (EU, 2024c) will evolve to include the reporting of relevant raw materials, water and energy use, alongside more disaggregated reporting, additional sectors ([11]) and updated reporting thresholds. This will capture wider and more complete environmental information to inform the effectiveness of these policies, and their links to their climate and circular economy counterparts.

The use of hazardous chemicals is also targeted by the new IED, which requires operators to incorporate management of risks from hazardous substances and analysis of safer alternatives in their environmental management system. This is linked to decreasing trends in the production of chemicals hazardous to health over the last 20 years, driven by chemicals policies such as the REACH Regulation. As shown in the indicator on the production of chemicals by hazard class in the EU indicator framework for chemicals, the production of chemicals hazardous to health relative to total chemical production decreased by 10% in the last decade and about 20% (or 47 million tonnes) in the last 20 years. Further reductions in the use of hazardous chemicals in both industrial processes and consumer products can be expected from the continuous implementation of REACH and other chemical legislation (including restriction proposals targeting specific pollutants under REACH, such as the one on PFAS (ECHA, 2024)), in line with the objectives and initiatives of the chemicals strategy for sustainability (CSS).

Whereas regulatory restrictions are expected to be the main driver towards the substitution of harmful substances, non-regulatory initiatives can further encourage the transition to safer and more sustainable chemicals. Examples of these initiatives are the guiding criteria and principles for the concept of 'essential use' (EC, 2024h) of the most harmful chemicals; the safe and sustainable by design (SSbD) (EC, 2022b) framework, a voluntary pre-market approach; or the information and performance requirements under Eco Design for Sustainable Product Regulation (ESPR) (EU, 2024d).

The EC has also delivered its proposal for a regulation on plastic pellet loss (EC, 2023d) to tackle this important source of unintentional microplastic releases in the EU, which can occur at different stages of the supply chain ([12]). The proposed

([10]) Based on modelling conducted by IIASA (2023) for the EC. The modelling compared a baseline with minimum and maximum feasibility scenarios. The maximum scenario considered a high level of industrial transformation and uptake of lower BAT-AEPLs. The minimum scenario considered gradual uptake of emission reduction measures. The modelling was done for air emissions of $SO_2$, NOx, $PM_{2.5}$ and NMVOC for all IED sectors.

([11]) Underground mining, aquaculture and medium combustion plants.

([12]) In 2021, around 57 million tonnes of pellets were produced in the EU and production is expected to reach about 79 million tonnes by 2030. It is estimated that between 52,140 tonnes and 184,290 tonnes were lost to the environment in the EU in 2019 (EC, 2023f).

regulation would require best practices for pellet handlers at all stages of the supply chain. Without regulatory actions, the amount of avoidable microplastic losses to the environment will not substantially decrease, even taking into account ongoing (voluntary) industry efforts and Member State legislation (e.g. in France). The proposal estimates a 54-74% decrease in losses compared to the baseline — equivalent to a 6% reduction in the total amount of unintentional microplastic releases (EC, 2023e) (see microplastics target analysis in Section 5.3).

As with any transition, the deep transformation of European industry to achieve the targets of the ZPAP, the Chemical strategy for sustainability (CSS) and climate policy will require substantial investments. Public investment and procurement at EU and Member State level must push decisively towards cleaner and low-carbon technologies. A crucial mechanism to channel private investments will be sustainable finance, which should play a key role in delivering the policy objectives of zero pollution and other EU Green Deal initiatives. The aim is to channel private investment to sustainable activities and future innovations that will support the transformation. A key tool to this end is the Taxonomy Regulation (EU, 2020a). It defines six environmental objectives ([13]) with delegated acts that contain technical screening criteria defining economic activities that can provide a 'substantial contribution' to achieving those objectives (see signal 'Zero pollution financing the investment gaps').

Implementation will be key to the success of the new and revised environmental legislation for industry. Industry should play a key role in contributing to the zero pollution ambition for 2050. Innovative technologies (see example in Box 3.2) will have to be widespread and applied efficiently, emerging pollutants will have to be targeted faster, and EU action should help support EU Member States in achieving a common playing field for industry and an even reduction of industry's environmental impacts.

Mario Draghi's 2024 report on industry's competitiveness, which contributed to the EC's priorities for the 2024-2029 period, also stresses that the EU must invest more in clean and strategic technologies, particularly in energy-intensive industries (Draghi, 2024). The report calls for Europe as leader of the clean and cutting-edge tech industry. Experiences and success stories on reducing industrial pollution through clean technologies can feed into this work.

## Box 3.2

**Emerging developments in industrial transformation: digital twins in industry 4.0**

The digital transformation of industry has been termed 'Industry 4.0' or the 'fourth industrial revolution' since 2011 (Schwab, 2017). One of its landmark technologies are digital twins. These are computer-based models of a manufacturing site, a process or a single processing unit. Several projects and partnerships in the latter stages of technical development have delivered promising results in using data measured by the instruments and equipment of manufacturing sites to optimise processes, predict equipment replacement and repairs, and coordinate maintenance periods with the fluctuation of raw material prices. By enabling more efficient and reliable operations, digital twins used at manufacturing sites have the potential of reducing pollution and resource use such as water and energy, minimise waste and reduce carbon dioxide emissions through energy efficiency (ETC WMGE, 2021).

([13]) Climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems.

## 3.3 Pollution from transport

**Key messages**

- Since 1990, emissions of NOx, NMVOCs, SOx, CO, and $CH_4$ have decreased significantly, with reductions of 51%, 76%, 82%, 90%, and 91%, respectively. However, ammonia ($NH_3$) and nitrous oxide ($N_2O$) emissions have increased by 121% and 35%.
- Between 2000 and 2022, $PM_{10}$ and $PM_{2.5}$ emissions from transport have decreased by 46% and 58%, including non-exhaust emissions from brakes and tyres.
- Methane emissions from maritime transport doubled between 2018 and 2023 due to liquefied natural gas (LNG)-fuelled vessels. NOx emissions increased 10% between 2015 and 2023 due to rising maritime traffic.
- Overall transport noise has not decreased significantly, despite the introduction of various policies to address transport-related noise such as regulations on motor vehicle sound levels and aircraft noise management.

In recent decades, policy measures have led to a decrease in air pollutant emissions from transport in the EU. This progress has been driven by the road transport sector, while emissions from the aviation and shipping sectors have increased for certain pollutants. The COVID-19 pandemic caused a dramatic reduction in transport volumes and emissions in 2020, but there was a visible upturn in pollution from transportation in 2021 as transport volumes rebounded. While most pollutants have declined since 1990, ammonia ($NH_3$) and nitrous oxide ($N_2O$) emissions have increased by 121% and 35% respectively, posing additional challenges for air quality and climate change mitigation. Between 1990 and 2022 (and thus including COVID-19 pandemic effects), nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), and NMVOCs and methane ($CH_4$) from transport decreased by approximately 51%, 82%, 90%, 76% and 91%, respectively (see indicator 'Emissions of air pollutants from transport').

In addition to these achievements, the EU made significant strides between 2000 and 2022 in reducing coarse ($PM_{10}$) and fine ($PM_{2.5}$) particulate matter emissions from transportation sources by approximately 46% and 58%, respectively. These reductions include non-exhaust emissions such as those originating from brake pad wear and tyre abrasion.

The EEA's *European Maritime Transport Environmental Report* (EMTER, 2025) indicates that methane emissions from maritime transport more than doubled between 2018 and 2023, driven by the increasing number of LNG-fuelled vessels. In 2022, these vessels accounted for 28% of the transport sector's total methane emissions. Nitrogen oxide (NOx) emissions have surged by an average of 10% across the EU between 2015 and 2023, mainly due to the expansion of shipping activities. The maritime sector's contribution to $PM_{2.5}$ emissions in transport has also slightly increased, peaking at 44% in 2019 and standing at around 42% in 2021. Additionally, its share of black carbon emissions in the EU-27 transport sector has steadily risen, reaching approximately 21% in 2021. EMTER highlights that ports are significant sources of NOx and PM pollutants that affect nearby cities.

EMTER 2025 estimates that the reduction in the size of the EU fishing fleet since 2015 led to a 17% decrease in NOx emissions and a 45% decrease in SOx emissions by 2023. Additionally, efforts to improve energy efficiency and the gradual adoption of alternative energy sources have further contributed to reducing emissions from fishing vessels.

Maritime transport also contributes to water pollution, primarily through oil spills and operational discharges such as grey water and exhaust gas cleaning systems (EGCS). While EGCSs help reduce SOx air emissions, they transfer the pollution from air to sea. Grey water discharges increased by 40% between 2014 and 2023, largely due to the growth in cruise ship operations. Underwater radiated noise (URN) sound energy density is also increasing across Europe's seas (See underwater noise pollution, Section 5.3). On the other hand, SOx emissions have decreased by about 70% since 2014, thanks to the introduction of sulphur emission control areas (SECAs). Beach litter originating from shipping and fishing has halved compared to a decade ago.

In addition to underwater noise from maritime transport, noise pollution is one of the most significant environmental impacts associated with terrestrial transport activities. In both urban and rural areas, road traffic emerges as the primary source of this noise pollution. While noise from aircraft and railways affects a smaller segment of the population, both remain important contributors to local noise issues. Over the past decade, various policies addressing transport-related noise have been introduced, including regulations on motor vehicle sound levels, the balanced approach to aircraft noise management and technical specifications for interoperability concerning rolling stock noise. However, these measures have not led to substantial reductions in transport noise at the overall EU level, as the projected growth in population and transport activities outpaces the benefits of these initiatives (see Section 4.2 for details).

Specifically in relation to the aviation sector, the recently published European Aviation Environmental Report (EASA, 2025) highlights the need to reduce emissions of air pollution and noise from the sector. Emissions of NOx from aviation have more than doubled since 1990, now contributing 14% to overall transport NOX emissions. While sustainable aviation fuels may help to address climate impacts, it is expected that NOX emissions will continue to grow and additional measures are needed to address this challenge. Aircraft engine emissions also present a risk in terms of emissions of ultrafine particles, with increased monitoring for these particles included under the revised Ambient Air Quality Directive. In relation to noise, the report estimates that around 10% of the population are exposed to aircraft noise above safe levels, with 649,000 people experiencing high levels of annoyance and 127,00 people suffering from sleep disturbance.

### *3.3.1 Recent policy developments*

The EU continues to address transport-related air pollution through directives, standards and local management plans, aiming for zero pollution by 2050. Some examples of recent policy developments in this area include the newly adopted EURO 7 standard for the type-approval of light and heavy-duty vehicles and EU Directive 2016/802 limiting the sulphur content of certain liquid fuels.

## 3.4 Pollution from agricultural production and food consumption (agri-food system)

**Key messages**

- The agri-food system is one of the most polluting production-consumption systems.
- Agricultural fertiliser and chemical pesticide use is still the main driver of nitrate and pesticide pollution in water, despite reductions in the use of pesticides.
- Agriculture is responsible for 93% of total ammonia emissions and reducing them remains a significant challenge.
- As a policy response to the negative impacts of pollution from agriculture, reducing nutrient and pesticide pollution is a joint objective of the EU's ZPAP, the Biodiversity Strategy for 2030 (EC, 2020a) and the Farm to Fork Strategy (EC, 2020b).

Pollution from agriculture is one of the most frequently-reported pressures under the Habitats Directive (EU, 1992) and the Birds Directive (EU, 2009), negatively affecting a wide range of habitats and species (EEA, 2020). Almost half of all pollution-related pressures reported under these two directives can be attributed to air, soil and water pollution from agriculture, mainly through diffuse pollution caused by the loss of nutrients and pesticides from the agricultural system. The amount of mineral fertilisers used by agriculture slightly increased from 2012 (9.5 million tonnes) to 2017 (11.7 million tonnes) and has moderately decreased since then. 2022 saw an estimated fertiliser use of 9.8 million tonnes — a very significant reduction in historical terms of 9.4% compared to 2021, mainly due to the sharp increase in fertiliser prices in 2022 (see indicator 'Estimated mineral fertiliser consumption by agriculture in the EU').

### *3.4.1 Outlook*

A faster transition to sustainable agricultural practices is needed to reduce pollution. Organic farming, alternative nutrient management practices, and more sustainable housing, feeding of livestock, improved manure use and management need to become more widespread. The share of the EU's agricultural land under organic farming is increasing, rising from 5.9% in 2012 to 10.5% in 2022 — an annual compound growth rate of 6%. However, to achieve the BDS and F2F target of 25% organic farming by 2030, the pace going forward will have to nearly double compared to the rate seen between 2012 and 2022 (see indicator 'Agricultural area under organic farming in Europe'). Restoring agro-ecosystems and enhancing nature-based solutions by increasing landscape features in agricultural land can also contribute to pest control, thus reducing the need for chemical pesticides and production costs (Klinnert et al., 2024). Transitioning to a circular economy is also effective in preventing pollution (e.g. through closing nutrient loops) (EEA, 2023b) and the agri-food sector holds great potential to apply circular economy principles.

Regarding nitrogen waste in the EU food system, the largest improvements in nitrogen use efficiency could be made in the livestock sector. Halving nitrogen waste requires both dietary shifts and farm-level actions (Leip et al., 2022).

There are diverse barriers for farmers to commit to agricultural systems and practices that can reduce pollution on a voluntary basis, including knowledge and investment needs, and uncertainties about the benefits and future opportunities. Lock-ins to the use of external inputs hinders innovation and the transition to sustainable, lower-input systems. More widespread uptake of these practices can be supported by targeted policy schemes with sufficiently ambitious targets, financial and advisory support, and by strengthening the implementation and enforcement of environmental legislation. Also, contribution from and cooperation among all the actors along the food value chain, social and technological innovation, and research and development are all needed for a systemic transformation to reduce pollution.

### *3.4.2 Recent policy developments*

The BDS for 2030 and the F2F aim to reduce the use and risk of chemical pesticides by 50%, reduce nutrient losses by at least 50% and reduce the use of fertilisers by at least 20% by 2030. They promote less intensive farming practices, integrated pest and nutrient management, organic farming and agroecological practices. All these measures could reduce pollution from agriculture while improving sustainability and agricultural production's resilience, with further benefits in reversing land degradation. These policy objectives are part of the Union's international commitment under the Kunming-Montreal Global Biodiversity Framework and contribute to the United Nations Convention to Combat Desertification (UNCCD) Strategic Objectives.

The recently adopted Nature Restoration Regulation (EU, 2024e), the revised Directive on Industrial and Livestock Rearing Emissions (EC, 2024f) and the proposed EU Directive on Soil Monitoring and Resilience (EC, 2023g) can reduce pollution from agriculture.

More recently, the final report from the Strategic Dialogue on the Future of EU Agriculture recommends, among other things, to enhance sustainable farming practices, including by reducing external inputs of mineral fertilisers and pesticides as well as improving nutrient management (EC, 2024i).

## 3.5 Pollution from consumption

### Key messages

- The environmental impacts linked to EU production have reduced over the last years. However, impacts linked to meeting EU consumption demands have been increasingly displaced to third countries and continue to grow.
- The EU consumption of material resources (biomass, fossil fuels, metals and non-metallic minerals) stands at 14 tonnes/capita/year — which is higher than in most countries worldwide — with no signs of reduction.

- The pollution impacts of EU consumption exceed planetary boundaries for particulate matter by a factor of nine (high confidence) and freshwater ecotoxicity by a factor of ten (medium confidence).
- Food, housing and mobility are responsible for more than 85% of these impacts, which calls for further measures on both production and consumption across these value chains.
- Projections for 2030 show that the EU has the potential to significantly reduce impacts in all environmental categories. Additional ambitious measures, such as more sustainable and healthy food diet, and deep renovation in buildings, could reduce the EU's environmental impact of consumption below even the ZPAP 2030 targets for almost all pollution-related environmental impact categories.
- Accelerating the circular economy and ensuring full implementation of recent policy developments is critical for reversing the upward trend of pollution impacts.

### *3.5.1 Introduction*

EU consumption demand drives material extraction and production processes, along with related resource use (e.g. of fossil fuels, mineral resources and water) which occur across complex product value chains within the EU and third countries. These processes lead to impacts on the environment and human health (UNEP, 2024). It is estimated that final consumption in the European region ([14]) contributes to 9% of global pollution impacts (UNEP, 2024). The ZPAP calls for less-polluting business models and consumption habits, in line with the objectives of the circular economy action plan (CEAP) (EC, 2020c), and the 8th Environment Action Programme, emphasising the need of living well within planetary boundaries.

This section tracks the impact of EU consumption on the environment and human health, considering impacts that occur over the whole value chain, using three indicators: Domestic material consumption (DMC), the JRC domestic footprint (DF) and the JRC consumption footprint (CF).

### *3.5.2 Domestic material consumption*

EU consumption of material resources (biomass, fossil fuels, metals and non-metallic minerals) remained relatively stable between 2010 and 2023. This accounts for materials coming from both the EU and third countries. Over the same period, the EU economy grew by 18%. This indicates a relative decoupling of material consumption from economic growth. However, current EU material consumption levels (at 6,192 million tonnes, see Figure 3.2 and indicator Domestic material consumption by main material category) equates to almost 14 tonnes per person per year, higher than in many other regions of the world (UNEP, 2024).

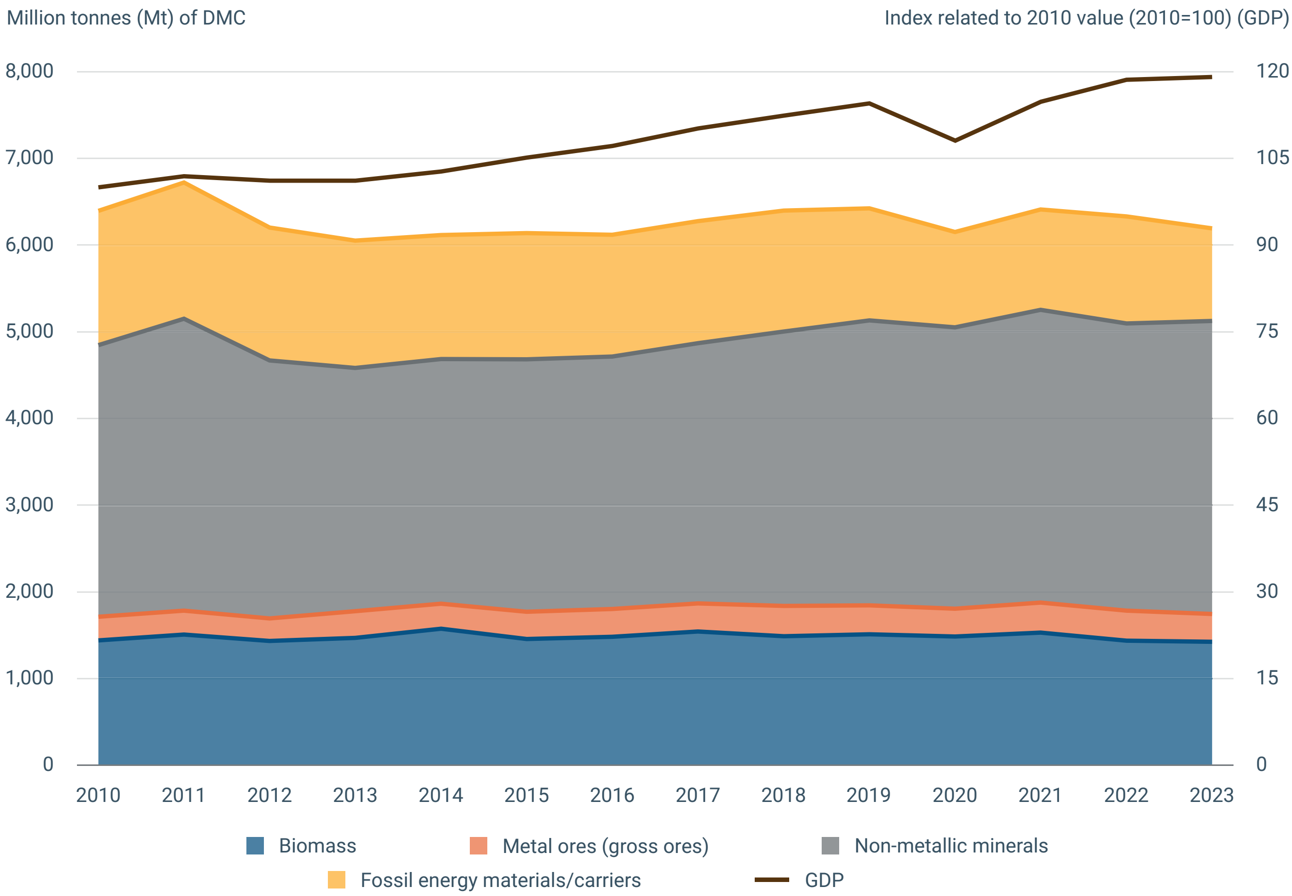
Over half of EU material consumption is linked to non-metallic minerals (e.g. sand, gravel or industrial minerals) but the materials with higher pollutant emissions per

([14]) Note that this includes more countries than the EU-27 Member States.

reference mass (e.g. tonne) are metals and fossil fuels. The consumption of metal ores increased by around 18% between 2010 and 2023, while the consumption of fossil fuels reduced by 31% over the same period, probably because of cross-sectoral energy efficiency and decarbonisation efforts in the EU and elsewhere.

Projections such as those by UNEP (2024) and OECD (2019) point to further increases in the consumption of materials in all world regions, including metals for Europe, to account, for instance, for the material needs of the energy transition (Bobba et al., 2020; Carrara et al., 2023). This underscores the urgency to deploy measures aimed at reducing the material demand stemming from EU consumption and emphasises the need for demand-side measures.

**Figure 3.2** **EU Domestic material consumption (DMC) by material category and Gross Domestic Product, 2010 to 2022**



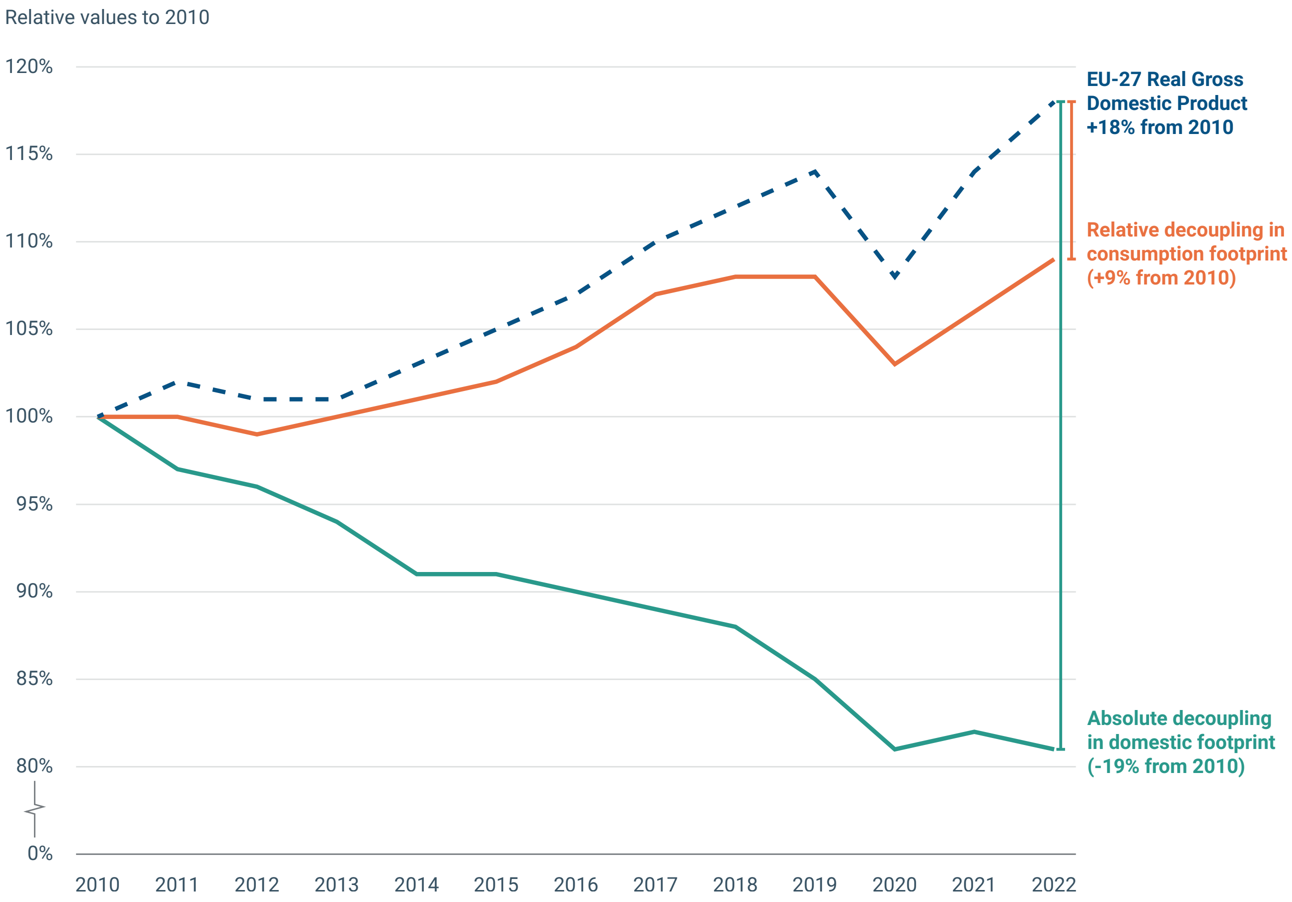

**Sources:** Based on EUROSTAT, 2024a and EUROSTAT, 2024b.

### *3.5.3 Environmental decoupling of the EU's consumption and domestic footprints*

Between 2010 and 2022, GDP has been steadily growing in real terms (+18%), while the same period has seen a 19% decrease in the EU's domestic footprint (Figure 3.3). This points to an absolute decoupling of environmental impacts from economic growth and underscores the positive effect of the implementation of EU environmental policy within its borders. These policies include measures such as banning or setting reduction targets for pollutants enacted through primary and secondary legislation, site operating permits and other regulatory approaches (Sanyé Mengual et al., 2019).

The situation shifts, however, when accounting for consumption building on net imports of raw materials, intermediate goods and final products from third countries. Over the same period, the consumption footprint increased by 9% (see Figure 3.3), which shows only a relative decoupling of the environmental impact of consumption from economic growth. This indicates that the EU is placing part of the burden of environmental impacts from consumption on third countries, as evidenced by trade figures such as crude oil or critical raw materials, where the EU relies on imports for 90% of its total consumption, as well as manufactured products.

**Figure 3.3 Evolution of the EU Domestic Footprint and EU Consumption Footprint compared with Gross Domestic Product index (2010=100%), for the period 2010-2022**

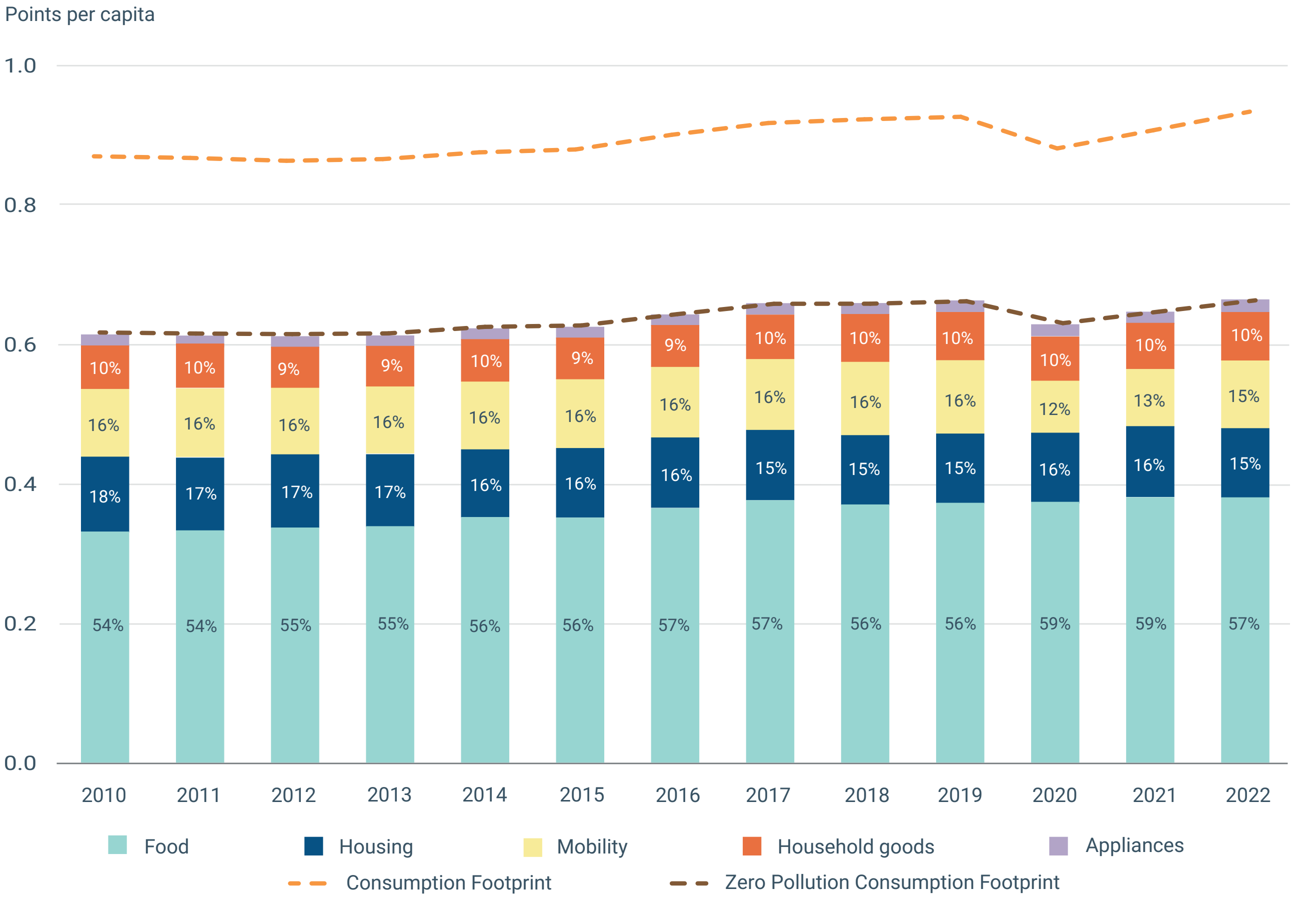



**Sources:** Sanyé-Mengual et al., 2025; Consumption footprint platform, 2024.

### *3.5.4 Consumption footprint by type of product and comparison to planetary boundaries*

The consumption footprint allows one to compare the pollution-related impact per products in their contribution to the single weighted score and with planetary boundaries (Sala et al., 2020). When considering the pollution-related impact categories collectively as a single score, food accounts for 57% of all impacts, followed by housing (15%) and mobility (15%) in 2022 (Figure 3.4).

**Figure 3.4** **Total EU Consumption Footprint 2010-2022, and by pollution-related domain (both weighted and normalised to an aggregate single score)**

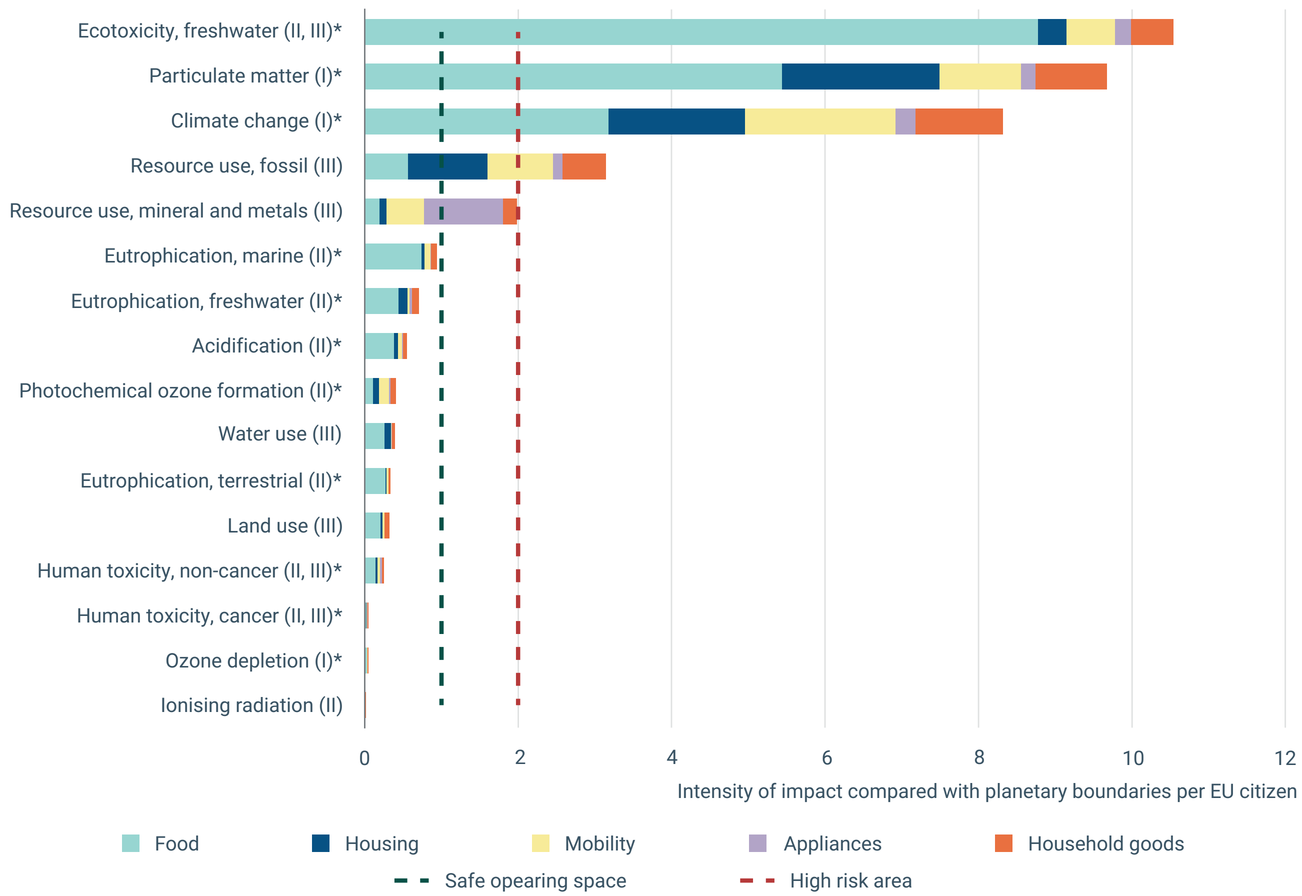



**Sources:** Sanyé-Mengual et al., 2025; Consumption footprint platform, 2024.

Figure 3.5 shows that the EU per capita consumption footprint in 2022 exceeds the planetary boundaries for particulate matter by nine times (high confidence) and eco-toxicity impacts (freshwater) by 10 times (medium-to-low confidence) (Consumption Footprint Platform). The utilisation of minerals and metals exceeds the 'safe operating space' by a factor of two (low confidence) and fossil resources by three times (low confidence). These latter are drivers for pollution as well as for climate change, which exceeds the planetary boundaries by a factor of eight (high confidence). While other pollutant-based impact categories per capita in the EU-27 perform much better, marine eutrophication is the only impact category approaching the limit of the 'safe operating space'.

Food stands out as the dominant product group responsible for pollution-related impacts relative to planetary boundaries. Resource use shows a more varied distribution amongst the product baskets, reflecting the relevance of fossil fuels, minerals, and metal resources in the production, manufacture, transport and use phases of products.

**Figure 3.5** **Contribution of the types of products to the Consumption Footprint and comparison with planetary boundaries in 2022 (EU-27, 2022)**




Sources: Adapted from Pasqualino et al. (2025). Model robustness between 'I' (or high confidence) and 'III' (or low confidence) of the impact assessment model used to assess each indicator is taken from EC, 2021b ([15]). ZP related categories are highlighted with and asterisk.

### 3.5.5 *EU consumption footprint scenarios (outlook)*

The consumption footprint data (with the latest available being 2022) were used for a thorough assessment of the potential impact of implementing actions with different levels of ambition, referring to 39 green transition targets (GTT) as part of the EGD targets up to 2030.

These targets were combined in three different scenarios: (i) 'No GTT' (considers no achievement of the green transition targets whilst assuming the continuation of present trends in the annual consumption patterns of products), (ii) 'GTT all targets' (builds on the 'No GTT' scenario by assuming also the achievement of all legally-binding green transition targets by 2030, and the non-legally binding reduction by 50% in the use and risk of chemical pesticides) and (iii) 'GTT Ambitious' (also encompasses the achievement of non-legally binding green transition targets such as a sustainable and healthy food diet, and deep renovation in buildings). Further information on scenario assumptions and modelling can be found in Pasqualino et al. (2025).

([15]) The results linked to toxicity are subject to high uncertainty as specified in the classification and description of the Environmental Footprint (3.1) method (EC, 2021b). The Commission Recommendation of 16 December 2021 (EC, 2021b) on the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations.

**Figure 3.6** **EU Consumption Footprint indicators related to pollutant emissions: past trends and outlook**

**Notes:** GTT= green transition targets. GTTs were selected based on two criteria: their direct relation to the ZPAP (see Box 1.1) and their capacity to be adequately represented by the consumption footprint model, thereby influencing the achievement of zero pollution targets. Unit of measurement of every Environmental Footprint impact category are expressed based on EC-JRC (2024).

**Source:** Adapted from Pasqualino et al. (2025).

Figure 3.6 shows that in the 'No GTT' scenario, most impact categories are projected to continue growing in line with expected consumption patterns up to 2030. Under the 'GTT all targets' scenario, three out of the eleven pollution-related impact categories are expected to decrease sufficiently to reach zero pollution target levels: freshwater indicators on ecotoxicity ([16]), eutrophication ([17]) and non-cancer human toxicity. It is only under the 'GTT ambitious' scenario that the desired zero pollution targets can be met and even lower environmental impacts can be attained. This is true for the following six pollution-related impact categories: ecotoxicity (freshwater), human toxicity (cancer and non-cancer) and eutrophication (freshwater, marine and terrestrial).

### *3.5.6 Recent policy developments*

The EU's environmental policy increasingly acknowledges the need to address the consumption of goods to mitigate environmental impacts. For instance, the EU regulated the consumption of certain goods that contribute to marine litter through the Single Use Plastics (SUP) Directive (EU, 2019a) (see Section 5.3 Marine pollution and ecosystems) and many Member States have imposed restrictions on specific substances and products (EEA, 2023a).

The SUP Directive also expands the use of extended producer responsibility, in line with the ambition of the ZPAP. The Ecodesign of Sustainable Products Regulation (ESPR) (EU, 2024d) aims to raise minimum environmental product requirements and to enable informed choices by EU private consumers and public bodies about the sustainability of products via ecodesign, labelling and digital product passports. The proposed Green Claims Directive (EC, 2023i) intends to prevent companies from making misleading environmental claims about products and services, while initiatives like the right to repair and the renovation wave boost more sustainable consumption options.

Leveraging and scaling up circular economy actions, building on existing initiatives derived from the European Green Deal and the full implementation of these and other measures will be crucial in the coming years for achieving environmental goals.

To make significant progress towards zero pollution targets, the EU needs to make further efforts to reduce its demand for materials, especially virgin materials. This requires action on both the supply (production) and the demand (consumption) sides. On the supply side, the EU should ensure the effective implementation of the policies in place and create a level playing field for imports as well as EU-produced goods. From a demand side perspective, the EU must consume more responsibly (e.g. using commodities and products with a lower environmental impact or greater durability), differently (e.g. embracing the sharing economy and public transport) and less (EEA, 2023a).

([16]) The results linked to toxicity are subject to high uncertainty as specified in the classification and description of the Environmental Footprint (3.1) method EC (2021b).

([17]) It is worth noting environmental impact of categories such as eutrophication or human toxicity might be subject to regional or local conditions where the boundaries are surpassed. As a result, the planetary boundary framework used in this study, which provides a global reference to the environmental impact, may hinder some of these local conditions.

## 3.6 Pollution from waste management

### Key messages

- Waste generation continues to increase in the EU which is not on track to meet the ZPAP target to significantly reduce total waste generation by 2030. The slight decrease (0.5%) between 2010 and 2022 can be mostly attributed to the economic slowdown due to the Covid-19 pandemic. Waste generation showed a net increase (+3.3%) between 2010 and 2022 when considering waste without major mineral waste from construction and mining.

- The EU is also not on track to meet the target of halving residual municipal waste by 2030, decreasing only by 16% since 2004 and reaching a plateau from 2015. These trends are due to the increasing generation of municipal waste, as well as an over-reliance on waste incineration and delays in introducing or improving recyclables collection. Waste prevention and stronger investments and incentives for separate collection and treatment to the highest recycling standards are needed.

- Pollution from landfills shows some positive trends, yet the monitoring of this source of pollution needs to be improved. In parallel, waste from waste sorting operations is increasing.

- Certain increasing waste streams such as waste electrical and electronic equipment (WEEE), batteries and textiles require improved separate collection and treatment to the highest recycling standards, to both reduce the pollution risk and to reap the resource potential of these wastes.

- Waste prevention and improved management are critical to have clean and safe materials cycles, which are in turn essential to ensure the benefits of the circular economy in the EU (such as reduced pollution, business opportunities and strategic autonomy).

### *3.6.1 Introduction*

Reducing waste generation — including also that of hazardous waste — can reduce the waste pollution burden on the environment and human health. The EU Waste Framework Directive establishes a hierarchy for waste management, under which waste prevention is preferable and which establishes additional obligations for the management of hazardous waste. The least preferable options for waste management are those associated with the highest level of pollution — e.g. waste incineration and the disposing of waste in landfills. The 2020 CEAP is also based on the waste hierarchy and introduced policies with the aim to reduce waste. The 8th EAP, the CEAP and ZPAP call for a significant reduction in total waste generation by 2030 and the ZPAP includes also the target of halving of residual waste (i.e. the waste that remains after recyclables have been separated).

### 3.6.2 Waste generation

Waste generation has continued to grow in the EU (see indicator 'Waste generation in Europe'). While waste generation per capita showed a slight decrease (0.5%) between 2010 and 2022, this is mostly due to the notable decline between 2018 and 2020 (close to 8% decrease) due to the COVID-19 pandemic and economic slowdown. Waste generation then continued increasing between 2020 and 2022 (3.6% increase), the last year for which data are available. Moreover, waste generation increased 3.3% between 2010 and 2022 when looking at the fraction without major mineral waste from mining and construction — which form a significant portion of total waste, while being generally less environmentally concerning due to its inert nature. It increased by 100kg between 2010 and 2018, with a decline from 2018 to 2020 (-84kg) during the COVID-19 pandemic and economic slowdown. Subsequently, the increasing trend continued until 2022. This indicates that the EU is not on track to achieving its zero pollution target of reducing total waste generation significantly. Waste generation is not expected to decrease, without putting in place very ambitious waste prevention measures.

### 3.6.3 Hazardous waste

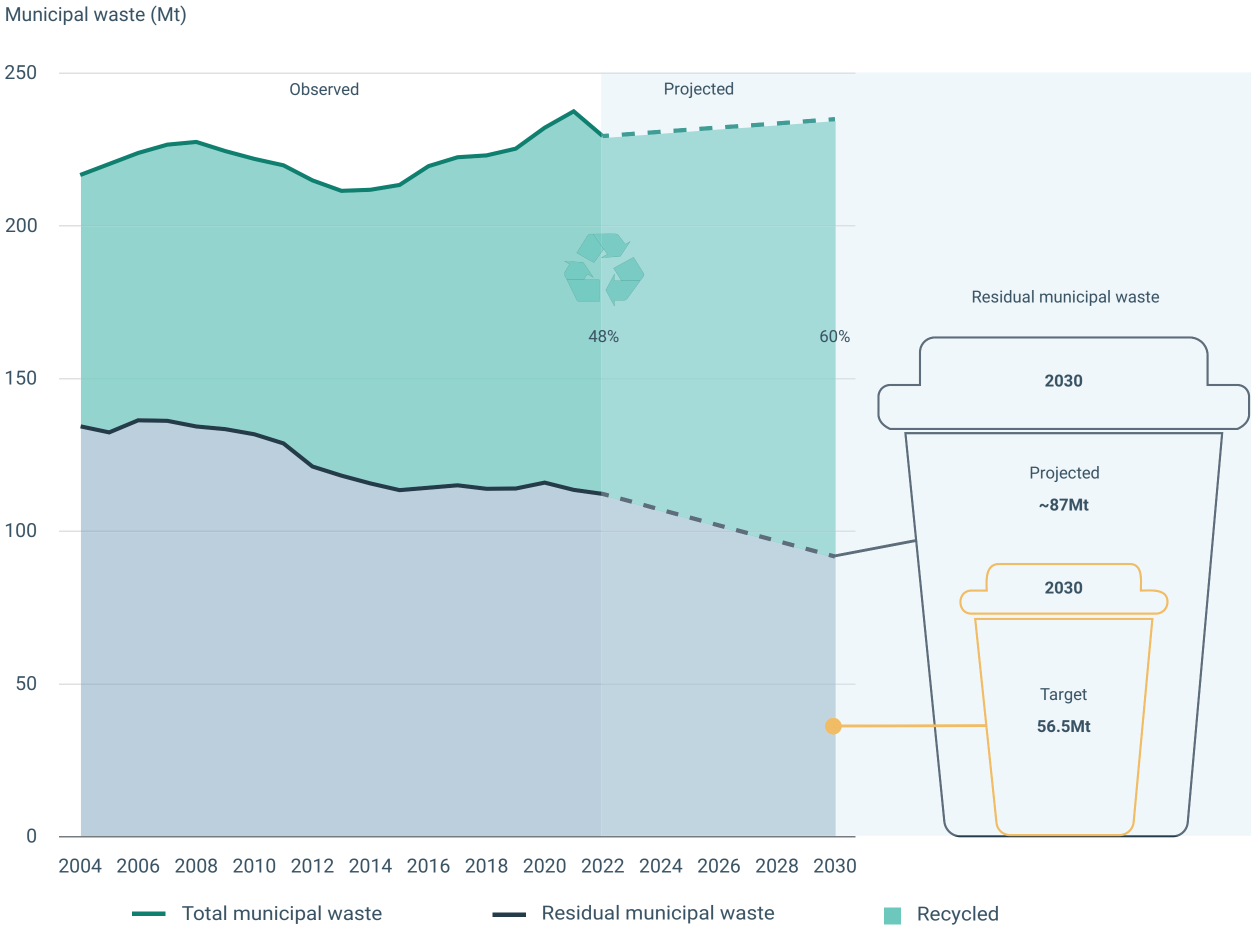
The generation of hazardous waste (see signal 'Hazardous waste generation in EU-27') is of particular concern because of the potential risks it poses to human health and the environment. Hazardous waste made up more than 5% of total waste (including major mineral wastes) (in 2022). It has been growing at a faster pace than total waste, rising by 31% between 2010 and 2022. There have been some notable increases in mineral waste from mining activities (especially between 2020 and 2022, partly due to the reclassification of some of this waste from non-hazardous to hazardous), construction and demolition and waste treatment, as well as waste from sorting residues, dredging spoils and discarded equipment (mainly e-waste, machines and technical components). Chemical wastes showed only a modest reduction. However, increased levels of hazardous waste generation can also signal improved segregation and better reporting of hazardous substances present in the economy.

The presence of hazardous substances in waste streams can impact human health and ecosystems and can serve as a barrier to the circular economy. Hazardous substances can be found in waste streams that are not necessarily classified as hazardous and which are present in commonly used products such as textiles and other domestic goods. An example of this is textile waste; while textiles (clothing, home textiles, leather) are estimated to be among the biggest contributors to PFAS pollution in Europe (EEA, 2024d), there are no specific provisions to classify textile waste containing PFAS as hazardous. PFAS are intentionally used in finished textile products to provide useful properties (water and oil repellence, thermal stability, etc.) and can accumulate in humans and lead to adverse health effects (EEA, 2024d). Wastewater treatment plants serving the textile industry have been shown to be a source of specific PFAS pollution (Eriksson et al., 2017). PFAS can also be released from textiles that are incinerated or disposed of in landfills. PFAS pollution from waste management or the lack thereof can be of higher concern when textile waste is exported to countries with less stringent waste regulations (EEA, 2024d) and where the amount of used textiles exported by the EU has tripled in the last two decades (EEA, 2023c). Another increasing concern is plastic waste, whose recycling rates are hindered by the presence of hazardous substances (see signal 'Plastics recycling in Europe: obstacles and options'). These examples highlight the need to not only improve the management of wastes containing substances of concern but to avoid contamination of valuable waste streams by these substances. This can be achieved by designing products that are safe and sustainable by design (EC, 2022b) and by improved regulation, such as the restriction proposal on PFAS (ECHA, 2024).

### *3.6.4 Waste management: residual municipal waste, recycling and landfilling*

The recycling of municipal waste steadily increased between 2004 and 2021 (while it decreased between 2021 and 2022) with a corresponding decrease in residual municipal waste — i.e. the waste that remains after recyclables have been separated (Figure 3.7). However, the likelihood of the EU meeting its zero pollution target of halving residual municipal waste by 2030 is challenged by increasing waste generation, over-reliance on incineration, a lack of progress towards meeting the recycling targets for municipal waste in many Member States (EEA, 2023d) as well as a limited collection and recycling capacity for bio-waste. Moreover, due to increased waste generation, even if all Member States meet the target for recycling (60% of generated municipal waste in 2030), meeting the target of halving residual waste will still be at risk. This highlights the need for waste prevention and stronger investments in and incentives for separate collection and treatment to the highest recycling standards. This will also help reduce demand for virgin materials and the environmental and health risks presented by substances of concern in waste.

**Figure 3.7 Past trends of total and residual municipal waste, and distance to target for residual municipal waste**




**Notes:** Residual waste is the waste that remains after recyclables have been separated.

**Sources:** Based on (EEA, 2022b), updated with data from Eurostat (2024c).

The amount of total waste (excluding major mineral wastes) that goes to landfill (see indicator 'Diversion of waste from landfill in Europe') has decreased in both absolute and relative terms. While landfilled household waste decreased by 61% between 2010 and 2022 and combustion waste by 2.6%, residues from sorting operations sent to landfill increased by 107%. Many Member States still need to speed up their efforts to meet the target to reduce the landfilling of municipal waste ([18]) to not more than 10% by 2035, as required in the Landfill Directive (EC, 2023h; EEA, 2023d). Moreover, the reduction of landfilling in some Member States has been partially based on the diversion of waste to incineration (EEA, 2023d), which can be beneficial in terms of energy recovery but is still lower in the waste hierarchy than other waste management operations.

### 3.6.5 *Pollution from waste landfill and waste incineration*

Emissions from landfills to air presented varied trends. Methane emissions from landfills decreased steadily between 2010 and 2021 (-42%), partially due to less biodegradable waste (a source of methane) being sent to landfill, pre-treatment of waste before landfilling and emissions being better managed (see indicator 'Air pollutant emissions from landfills') ([19]). Carbon dioxide emissions fluctuated somewhat and have increased slightly in recent years (+3% between 2019 and 2022). Ammonia emissions increased during the same period; however, this is based on intermittent reporting by facilities and significant variations in the data received. As for soil and water pollution, landfill leachate management remains a problem for both legacy and operating landfills and also for wastewater treatment plants, yet accurate data to monitor contaminants from this source is scarce. Leachate can carry toxic pollutants, including emerging pollutants, heavy metals and PFAS (see signal 'Leachate pollution from landfills'). Landfills can also contribute pollution in the form of microplastics, which can leak into aquatic and terrestrial environments, carrying harmful chemicals such as persistent organic pollutants and heavy metals (see signal 'Impacts of microplastics on health').

Waste incinerated (with or without energy recovery) increased steadily between 2010 and 2021, with a small decrease in 2022 (see indicator 'Pollutant emissions from waste incineration'). This increase has been less pronounced compared to the increase in recycling and composting. The incineration of municipal waste has doubled since 1995, seeing an 11% increase between 2010 and 2022. Total pollutant emissions to air from incineration facilities have remained rather stable, which may be attributed to an improved control on pollutant emissions to air because of the adaptation period of these plants to the BATs conclusions for the sector (see indicator 'Pollutant emissions from waste incineration').

### 3.6.6 *Specific waste streams: WEEE, batteries and renewable technologies*

Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams in the world (see RMIS — E-waste). In the EU, the rate of placing new items on the market has been greater than the increase in collected WEEE and Member States' struggle to achieve the collection targets set out in the WEEE Directive (EU, 2012) (see indicator 'Waste electrical and electronic equipment (WEEE) collection rate'). The total amounts of EEE placed on the market have risen 80% between 2015 and 2022, moving from 18 to 28 kg/capita. And the collection rate was 40.6% in 2022, below the 2019 target defined in the WEEE Directive (65%). The EC is currently evaluating this directive to determine if a review is needed. Inadequate

([18]) Municipal waste includes waste from households and waste of similar nature from other sources such as services and institutions.
([19]) These trends are based on data that cover only landfills under the scope of the E-PRTR regulation (EU, 2024c), i.e. limited to specific pollutants and the biggest facilities.

WEEE management can lead to dangerous substances entering the environment, which can pose substantial risks to both ecosystems and human health. Emerging occupational risks may also arise from facilities managing waste streams with hazardous substances such as WEEE (see signal 'Occupational exposure in recycling facilities').

As with WEEE, a substantial quantity of waste batteries is being generated in Europe. The amounts of portable batteries and accumulators sold increased 44.5% between 2013 and 2022, and waste battery collection rates increased only from 37.8% to 46.5%. According to the new regulation on batteries and waste batteries (EU, 2023a), producers have to collect at least 63% of waste portable batteries by the end of 2027 and 73% by the end of 2030, and 51% for waste batteries from light means of transport by the end of 2028 and 61% by the end of 2031. Waste batteries are anticipated to significantly grow in the coming years due to the green energy transition (EEA, 2021; Carrara et al., 2023) (see indicator 'Collection rate for portable batteries and accumulators'). Despite differences in their chemical composition and construction, one common characteristic of most battery types is that they contain heavy metals like cadmium, nickel or lead. Most Member States have experienced a rise in battery sales, with notable increases in some countries. Moreover, the increasing number of waste batteries from mobility applications — i.e. in electric vehicles (EVs) and light means of transport (LMT) such as e-bikes — is an increasing issue. The new Regulation on batteries and waste batteries mentioned above addresses these issues through ambitious collection targets (the mandatory collection of all EV batteries and gradually implemented targets for the collection of LMT batteries), as well as targets for the recycling efficiency for the different battery chemistries and for the recovery of materials. The regulation also lays down provisions for the safe handling and treatment of waste batteries.

The fact that technologies are not yet fully developed for recycling materials from renewable energy technologies (e.g. photovoltaic panels, wind turbines) poses an additional challenge to waste management when these products reach their end of life (signal 'Recycling of materials from green energy technologies').

The increasing generation rate of WEEE as well as batteries and renewable energy technologies waste presents a significant pollution risk if not safely collected and recovered. To address this risk, the full implementation of the legislation in place is needed to increase at speed the collection and recycling capacities of these waste streams. Improved collection and recycling could also provide an important source of secondary raw materials.

### *3.6.7 Recent policy developments*

Since the publication of the first ZPMA report, relevant provisions in EU waste legislation have been developed and/or reached implementation stage. For instance, to prevent contamination among other reasons, Member States must establish separate collection for hazardous waste fractions and textiles produced by households by 1 January 2025. Since the end of December 2023, bio-waste has needed to be separately collected or recycled at its source. The new Packaging and Packaging Waste Regulation aims to prevent and reduce packaging waste, including encouraging reuse and its improved recycling. The regulation includes targets for the reduction of packaging waste per capita (at least 5% reduction by 2030, 10% by 2035 and 15% by 2040, compared to 2018). It includes also targets for the recycling of packaging, as well as restrictions on certain single-use plastics. These rules partly build on the measures introduced by the Single Use Plastics (SUP) Directive (EU, 2019a). Member States have reported, for the first time in 2024, reuse measures to prevent waste generation (EEA, 2023e).

New legislation has been developed to reduce the adverse impacts of specific waste streams. The new Regulation on Batteries and Waste Batteries (EU, 2023a) introduces tighter restrictions on the use of some hazardous substances, reinforces collection targets, and introduces targets for recycling efficiency and the recovery of specific materials. The 2023 regulation proposal for End-of-Life vehicles (ELV) (EC, 2023d) aims, among other aspects, to improve the collection of ELVs and increase their recycled content. The CRMs Act (see also above) sets a target that at least 25% of the EU's annual consumption of strategic raw materials comes from recycling by 2030. The WEEE Directive is also under revision.

The new Regulation on Waste Shipments (EU, 2024f) establishes rules to increase the EU's responsibility for its waste, including the banning of plastic waste exports to non-OECD countries from 2026. In addition, the Basel Convention Plastic Waste Amendments aims to better control transboundary plastic waste movement. The IED has been also revised to include landfills under the list of activities that need to operate according to the BAT conclusions specified in the relevant BREF (BAT Reference Document), which now needs to be developed ([20]).

Given the current challenges, the full implementation of the legislation in place is needed to rapidly increase collection and treatment capacities, both in general and in particular for fast-increasing waste streams. Ambitious waste prevention measures are also needed for both hazardous and non-hazardous waste. Next to the focus on implementation, the political guidelines of EC President von der Leyen underline the importance of the circular economy to create a market demand for secondary materials and a single market for waste, notably in relation to critical raw materials.

([20]) Incineration plants and other waste management facilities already have BREFs.

# 4 Pollution impacts on human health

As identified in the previous chapter, pollution is an inevitable consequence of making goods, providing services and consuming both. This pollution significantly impacts human health through various pathways, including air, noise, soil and water. For instance, air pollution — caused among others by industry, transport and domestic activities — leads to cardiovascular, respiratory, metabolic and neurodegenerative diseases that affect millions globally. Noise pollution is linked to annoyance, cardiovascular disease, diabetes and sleep disturbance. Chemical pollution present in the environment can bioaccumulate in the food chain posing risks to human health; heavy metals and organic pollutants contribute to a range of health issues such as cancer. At present, 10% of annual premature deaths in the EU-27 are related to environmental pollution (see 'Premature deaths caused by environmental pollution').

Curbing or better preventing pollution will reduce related premature deaths, but importantly it will also improve quality of life by reducing chronic illnesses. Reducing exposure from pollution will also increase resilience within the population in dealing with other stressors — such as heatwaves due to climate change. Achieving the ambitious targets set forth in the ZPAP will require sustained efforts firmly based on the One Health approach that acknowledges the interconnectedness of human, animal and environmental health.

## 4.1 Air pollution and human health

### Key messages

- Significant progress has been made in reducing the impact of particulate matter (PM) air pollution, with a 45% decrease in premature deaths attributable to $PM_{2.5}$ exposure between 2005 and 2022.
- 19% and 9% of EU residents, respectively, were exposed to ozone and $PM_{10}$ levels above EU legal standards in 2022.
- More than 83% of urban residents are exposed to all air pollutants above safe levels recommended by the WHO, except $SO_2$ and benzo(a)pyrene (BaP), indicating persistent air quality problems.
- The EU is on track to meet the ZPAP target of reducing premature deaths by 55% in 2030, as compared to 2005. This progress depends, however, on the successful implementation of current and proposed policies, including those related to energy and climate mitigation.

### *4.1.1 Introduction*

Air pollution is a significant cause of disease and mortality in Europe, and the foremost environmental health risk (WHO, 2023a). Over recent decades, the EU has implemented a range of measures aimed at setting limits and target values for both emissions and ambient concentrations of key pollutants to protect human health and ecosystems. While these measures have resulted in significant improvements in air quality, there continue to be significant hurdles to the long-term vision of zero pollution.

Furthermore, the increased frequency of heat waves in Europe, when coupled with exposure to air pollution, significantly increases the risk of mortality, particularly in people with pre-existing health conditions (EEA, 2023f). Reducing air pollution improves the basic health conditions of the population and reduces these combined risks to health and wellbeing.

The revised AAQD (EU, 2024g) is a big step towards aligning air quality standards more closely with WHO recommendations and delivering a zero pollution objective for air quality by 2050.

### *4.1.2 Air quality standards in Europe*

More than 70% of EU residents live in urban areas characterised by a high population density and economic activity. Data from 2022 show that while the vast majority of these people are exposed to pollutant levels below the current EU air quality standards, the exposure is above the stricter WHO guideline values (WHO, 2021). For example, in 2022, 96% of the urban population was exposed to $PM_{2.5}$ above WHO recommendations, with similar figures of 94% for ozone and 88% for $NO_2$ (Figure 4.1) (see indicator 'Exceedance of air quality standards in Europe').

## Box 4.1

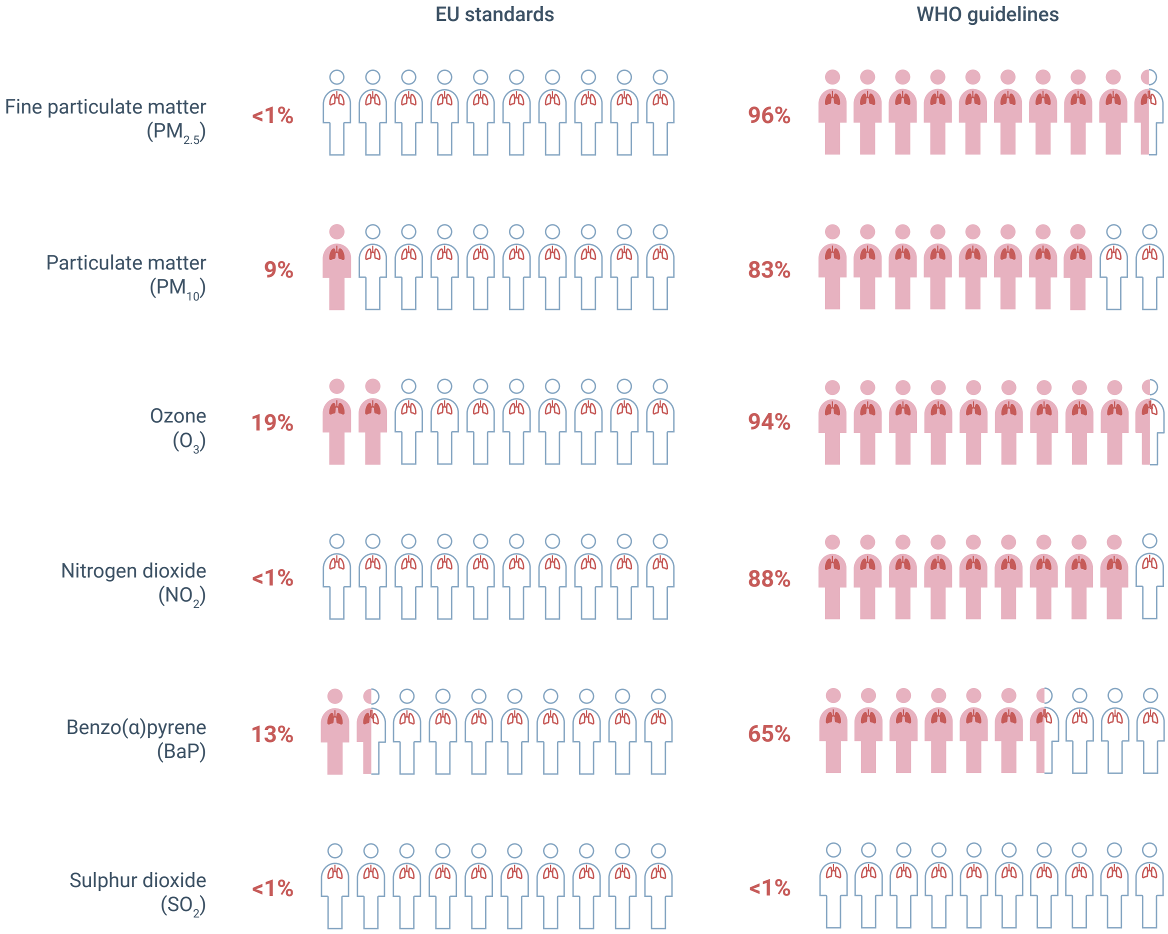
**Air pollution in EU cities**

Many European cities suffer from poor air quality and regularly exceed both the European standards prescribed by the Ambient Air Quality Directive (AAQD) and guidelines recommended by the World Health Organization (WHO). For $PM_{2.5}$, few cities manage to keep concentrations below the levels recommended by the WHO, i.e. 5µg/m$^3$ on an annual basis. Actions have been proposed and taken at the international, national and urban scales to reduce air pollution. While they have undoubtedly resulted in an overall improvement in air quality over the years, there are still problems which are local to specific regions and cities. A key issue is thus determining at which scale to act to effectively tackle these remaining air pollution problems. Central to this, for cities, is a quantitative assessment of the different origins of air pollution (urban, regional, national and international) and of their impacts. This is to support the design of efficient and effective air quality plans, which are a legal obligation for countries and regions whenever exceedances occur.

To be effective, pollution reduction plans must be designed and applied to target the most polluting sectors at the appropriate spatial and temporal scales. In this context, quantifying the contribution to local pollution caused by the city's own emissions becomes a crucial element to determine whether actions need to be applied locally or at the regional, national or continental scales. This has important governance consequences for the effective control of air pollution. Map 4.1 illustrates the cities' contribution to their air pollution in the EU. For many cities, local actions at the city scale are an effective means of improving $PM_{2.5}$ air quality.

The JRC periodically publishes the Urban $PM_{2.5}$ Atlas that quantifies the spatial (e.g. urban, country) and sectoral (transport, residential, agricultural) contributions to $PM_{2.5}$ levels in 700 urban areas across Europe.

**Figure 4.1** **Share of the EU urban population exposed to air pollutant concentrations in 2022 above 2008 EU standards and 2021 WHO guidelines**

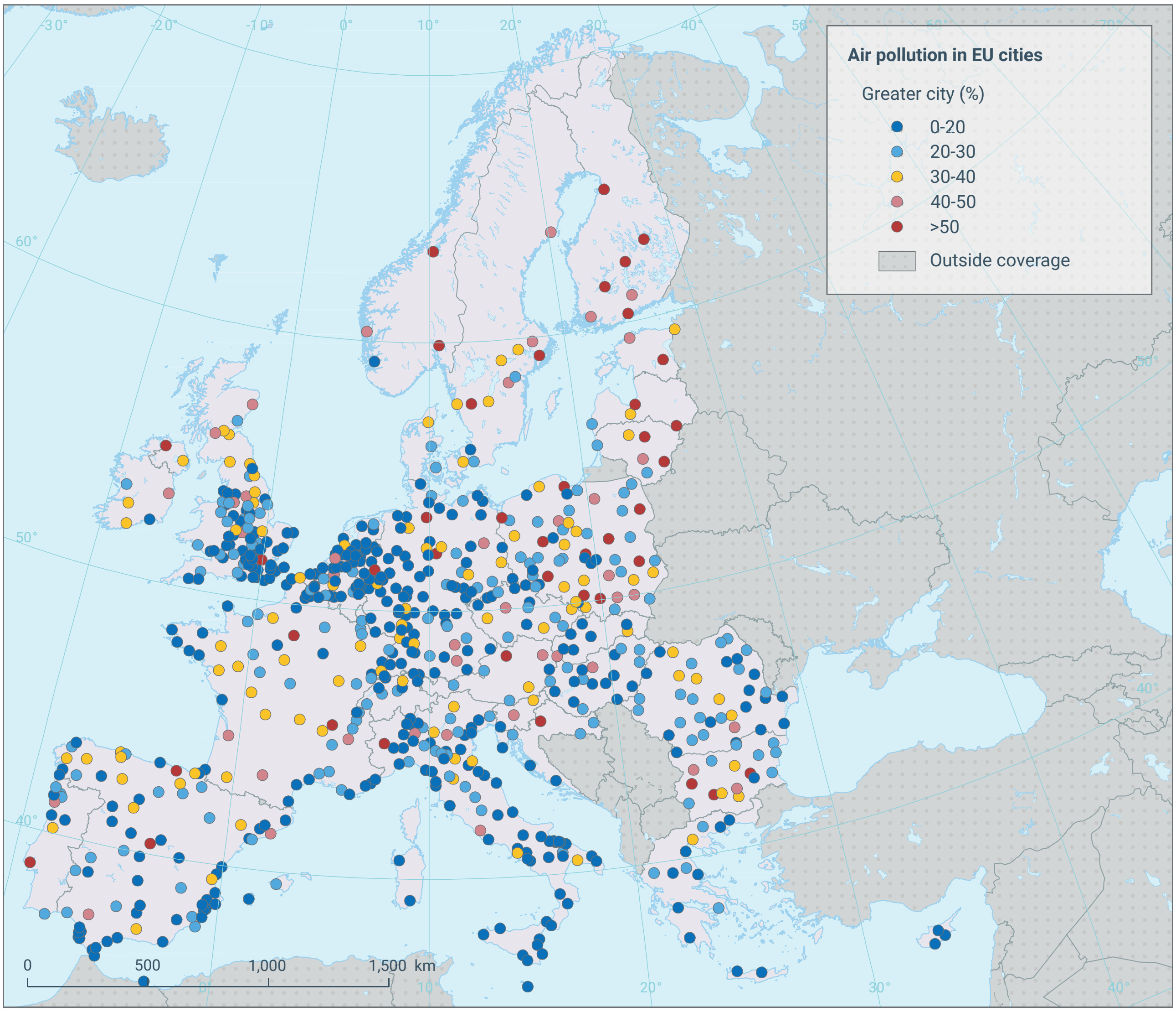



**Notes:** Exposure above EU standards: the EU urban population is exposed to $PM_{2.5}$ annual concentrations above 25µg/m³; $PM_{10}$ daily concentrations above 50µg/m³ for more than 35 days per year; $O_3$ maximum daily 8-hour mean concentrations above 120µg/m³ for more than 25 days per year; $NO_2$ annual concentrations above 40µg/m³; Benzo(a)pyrene (BaP) annual concentrations above 1ng/m³; and sulphur dioxide ($SO_2$) daily concentrations above 125µg/m³ for more than three days per year.

Exposure above WHO guidelines: the EU urban population is exposed to $PM_{2.5}$ annual concentrations above 5µg/m³; $PM_{10}$ annual concentrations above 15µg/m³; $O_3$ maximum daily 8-hour mean concentrations exceeding 100µg/m³ for more than 3-4 days per year; $NO_2$ annual concentrations above 10µg/m³; BaP annual concentrations above 0.12ng/m³; and $SO_2$ daily concentrations above 40µg/m³ for more than three or four days per year.

**Source:** EEA, 2024e.

**Map 4.1 Relative contributions of EU cities to their own pollution ($PM_{2.5}$ levels)**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

**Notes:** Cities are defined as greater cities, i.e. including a core city as well as a commuting zone. For details, see the Urban $PM_{2.5}$ Atlas

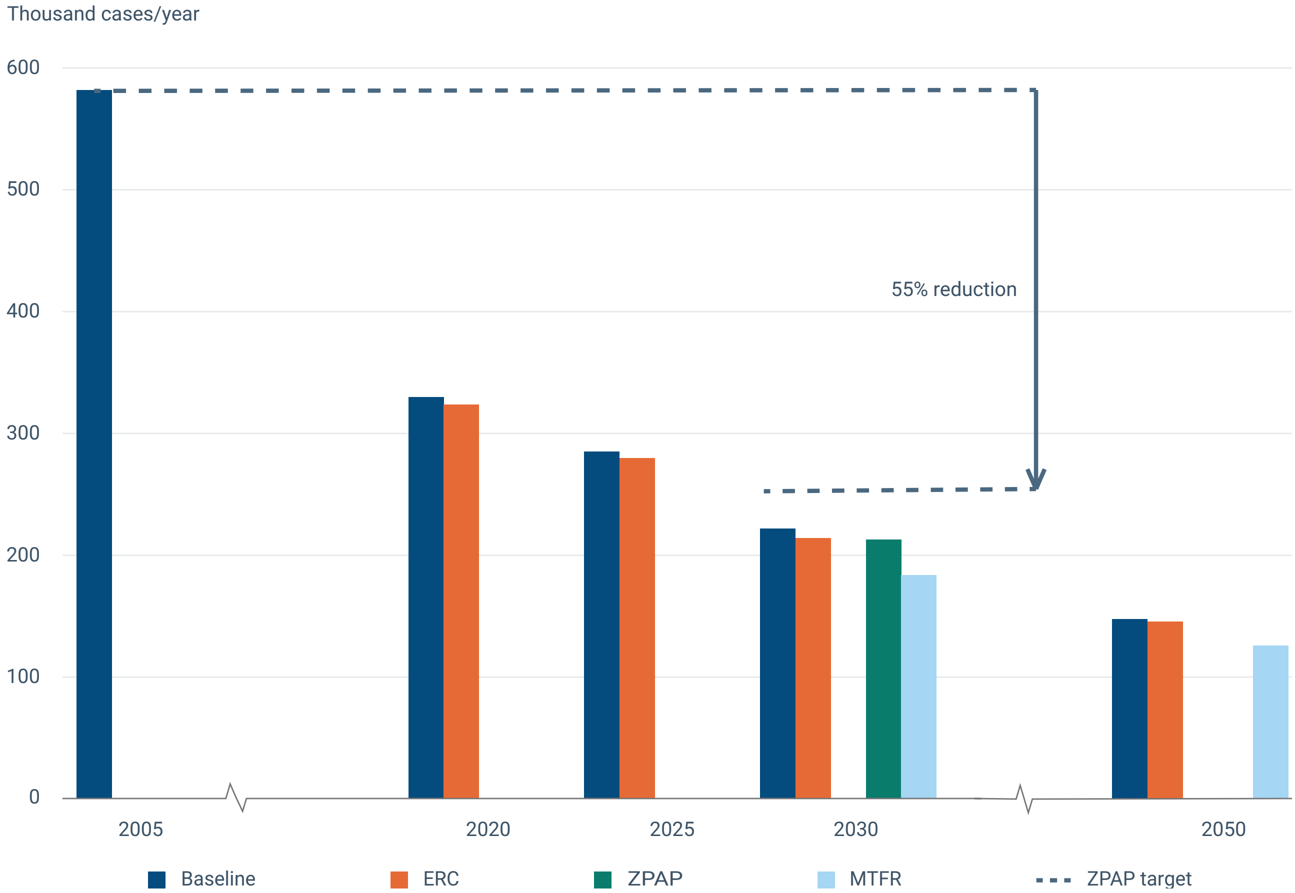
**Sources:** Thunis et al., 2023.

### *4.1.3 Exposure to fine particulate matter and burden of disease – progress and outlook*

Between 2005 and 2022, air quality improved across Europe, particularly in urban areas. In the same period, premature deaths attributable to exposure to fine particulate matter less than 2.5µm ($PM_{2.5}$) fell by 45% (see indicator 'Premature deaths due to exposure to fine particulate matter in Europe'). The reduction in premature mortality is due to the implementation of various EU, national and local policies and measures aimed at enhancing air quality. If the number of premature deaths continues to fall at the rate seen between 2005 and 2022, the 55% zero pollution target will very likely be met by 2030. However, reaching this target would still mean around 200,000 premature deaths attributable to air pollution per year in 2030. Efforts must hence continue to achieve the zero pollution ambitions beyond 2030, in particular by implementing the new Directive swiftly. Other environmental factors are also increasing the health risks posed by air pollution, in particular the combined risk with heat exposure and increasing knowledge on the risks posed by other pollutants such as ultrafine particles.

The modelling undertaken for the 4th Clean Air Outlook (EC, 2025) shows a decline in premature deaths in 2030 of about 62-68% compared to 2005, across all scenarios modelled. The zero pollution target of reducing premature deaths by 55% in 2030 as compared to 2005 is already achieved under baseline assumptions. This result demonstrates the impact and air quality benefits of the clean air, energy and climate mitigation policies included in the baseline, provided they are fully implemented.

**Figure 4.2 Comparison of the cases of premature deaths attributable to the exposure to total anthropogenic $PM_{2.5}$ in the EU-27, for the analysed scenarios**



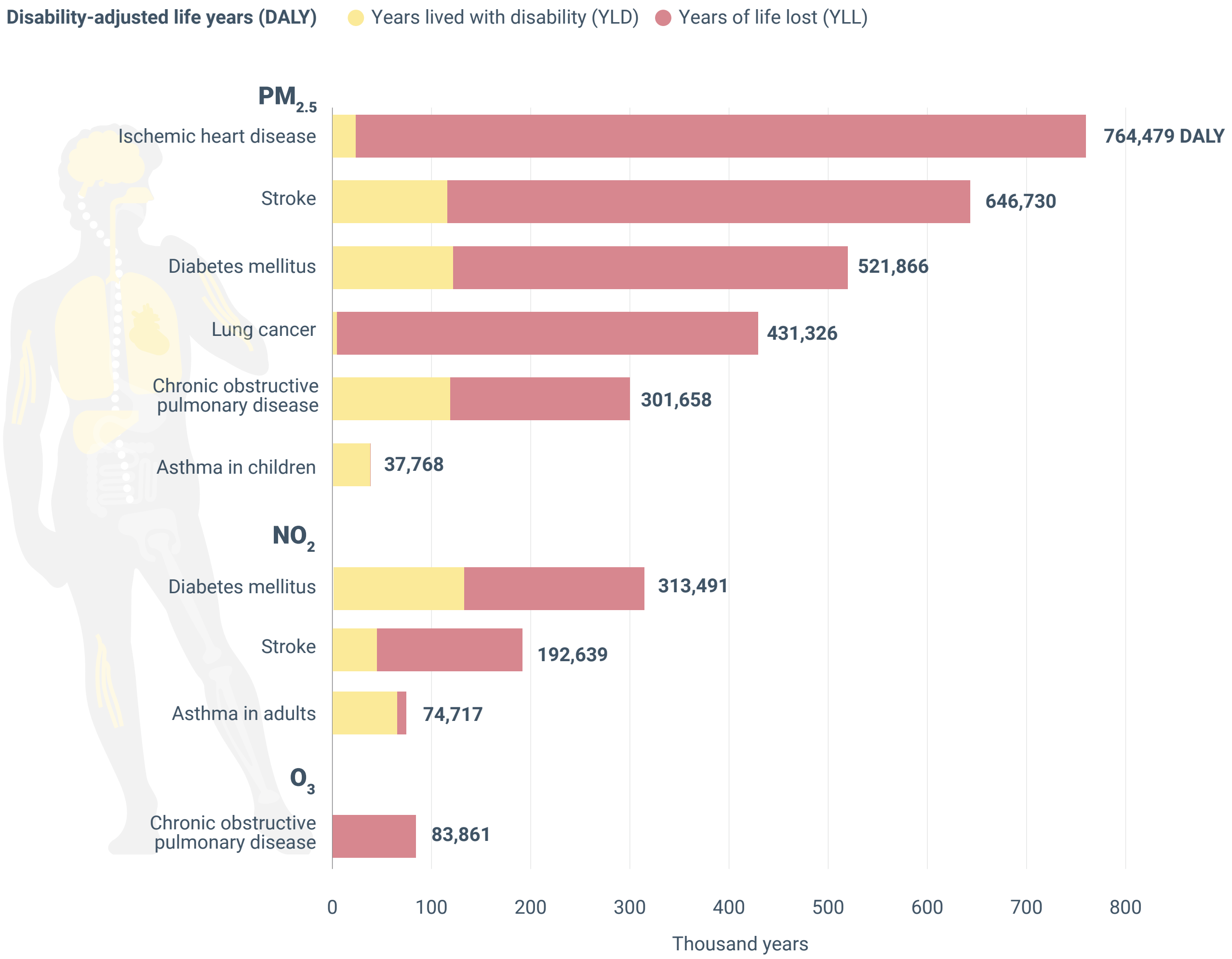

**Notes:** The 55% reduction in premature deaths from 2005 levels corresponds to the ZPAP target.
MTFR, Maximum technically feasible reduction.

**Sources:** 4th Clean Air Outlook (EC, 2025).

The EEA also estimates the mortality due to ozone ($O_3$) and nitrogen dioxide ($NO_2$). In 2022 in the EU-27, 70,000 deaths were attributable to exposure to $O_3$ concentrations above the WHO guideline level of 60µg/m³ and 48,000 deaths were attributable to exposure to $NO_2$ concentrations above the WHO guideline level of 10µg/m³ (EEA, 2024f)

Exposure to air pollution not only causes mortality but also a range of specific diseases. The overall harm to human health is defined using the total burden of disease concept. The EEA has estimated for the first time the total burden of disease for selected pollutant-disease pairs for the year 2022, as shown in Figure 4.3. The allocation of the burden of disease attributable to air pollution varies notably across specific air pollution-related diseases, with mortality and morbidity exerting differing levels of influence. In the cases of lung cancer and ischemic heart disease, the total burden of disease results predominantly from mortality. Conversely, the contribution of morbidity to the total burden of disease is much more relevant for asthma. This highlights the importance of considering morbidity to avoid underestimating the overall harm to human health (see signal 'Morbidity due to exposure to air pollution').

**Figure 4.3 Burden of disease (expressed as mortality and morbidity) for $PM_{2.5}$ and $NO_2$, 2022**




Notes: Mortality (red) and morbidity (yellow) were calculated for selected pollutants based on concentration-response functions as explained in Soares et al. (2023) particulate matter below 2.5 µm ($PM_{2.5}$) and nitrogen dioxide ($NO_2$).

Source: EEA, 2024f.

### *4.1.4 How air pollution impacts mental health*

While the link between physical health and pollution is well-documented — with substantial evidence indicating that a significant portion of Europe's disease burden is due to human-caused environmental pollution (EEA, 2019) — the impact of air pollution on mental health is not as well understood. Research increasingly points to inflammation and oxidative stress as key health conditions linking air pollutants to mental health issues. Numerous studies have highlighted the impact of long-term exposure to air pollution on psychiatric disorders such as anxiety, bipolar disorder and depression, as well as suicide risk. Long-term exposure to $NO_2$, $PM_{2.5}$ and respirable $PM_{10}$ is also associated with cognitive decline, increasing the risk of dementia in the elderly and exacerbating diseases like Alzheimer's. A reduction of air pollution may therefore also improve mental health. However, relevant data are not yet available to be able to estimate a trend.

## Box 4.2

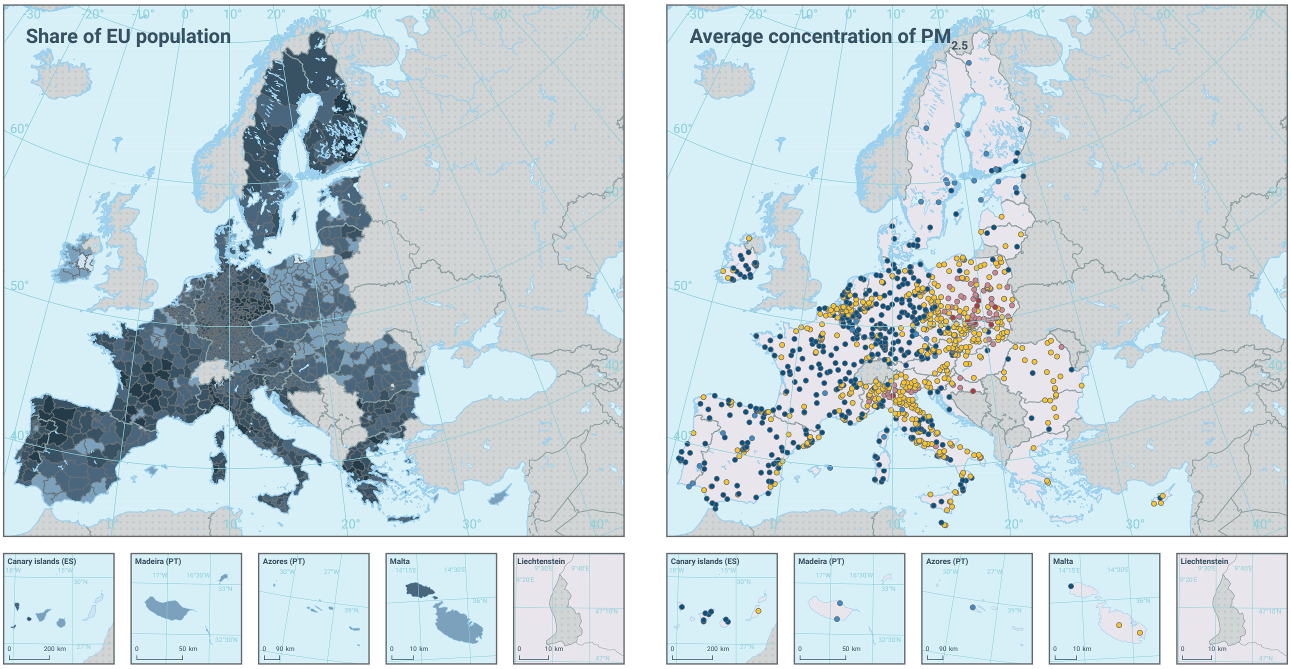
**Demography and inequalities in exposure to air pollution**

Economic development, urbanisation, energy consumption and transportation are major driving forces behind air pollution in the EU, especially in large cities. Population density plays a big role in air pollution: cities with high population density often have the poorest air quality. The EC Demography Reports 2020 and 2023 (EC, 2020b, 2023a) and the proposal for the revision of the AAQD warned that inequalities in access to clean air and environmental resources can disproportionately affect certain demographic groups, contributing to health disparities and social inequities.

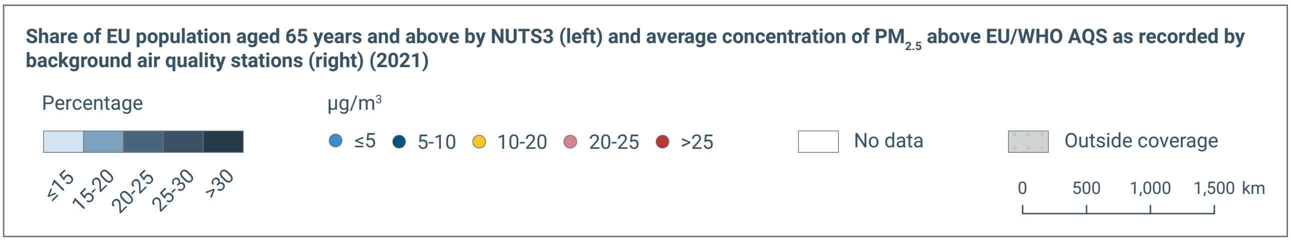
The Atlas of Demography (AoD) illustrates the concentrations of fine particulate matter ($PM_{2.5}$) as recorded by European air quality monitoring stations. The map shows that while air quality is below the WHO's Air Quality Standards in many EU countries, the situation is particularly worrying in some Member States, including Italy and Poland. The Atlas also shows that people aged 65 and above (as well as children) are most negatively affected by air pollution. Moreover, some of the most polluted regions spatially coincide with the poorest regions in the eastern part of Europe. Despite improving trends in air pollution in both the richest and the poorest regions of the EU over the 2007-2021 period, inequalities remain with levels of $PM_{2.5}$ concentrations consistently higher by around one third in the poorest regions.

Published by the EC Knowledge Centre for Migration and Demography (KCMD), the AoD is an online reference tool guiding for policymakers, practitioners and the general public in the discussion about the role of demography in EU policies. It underlines the importance of factoring demographic insights and the needs of specific age groups in the design of EU policies, particularly in the context of the ageing EU population. By understanding the interconnected nature of demographic change, clean air policies and inequalities, policymakers and advocates can work towards more inclusive and sustainable solutions that benefit all members of society.

**Map 4.2 Share of EU population aged 65 years and above, by NUTS3 (%) (left) and average concentration of $PM_{2.5}$ above EU/WHO air quality standards as recorded by background air quality stations (%) (right) in 2021**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO




**Notes:** Please find the interactive map here.

**Source:** EEA, 2022c

## 4.2 Noise pollution and human health

**Key messages**

- Over 20% of the EU population lives in areas where transport noise levels exceed the thresholds considered harmful to health under the Environmental Noise Directive (END). When the more stringent WHO thresholds are applied, this figure increases to over 30%.
- Between 2017 and 2022, the number of people exposed to harmful noise levels slightly decreased. During the same period, the number of people suffering high annoyance fell by around 6%.
- The number of people exposed to noise is anticipated to decrease. However, based on current projections, a reduction in the number of people chronically disturbed by transport noise levels of at least 30% by 2030 is not possible.

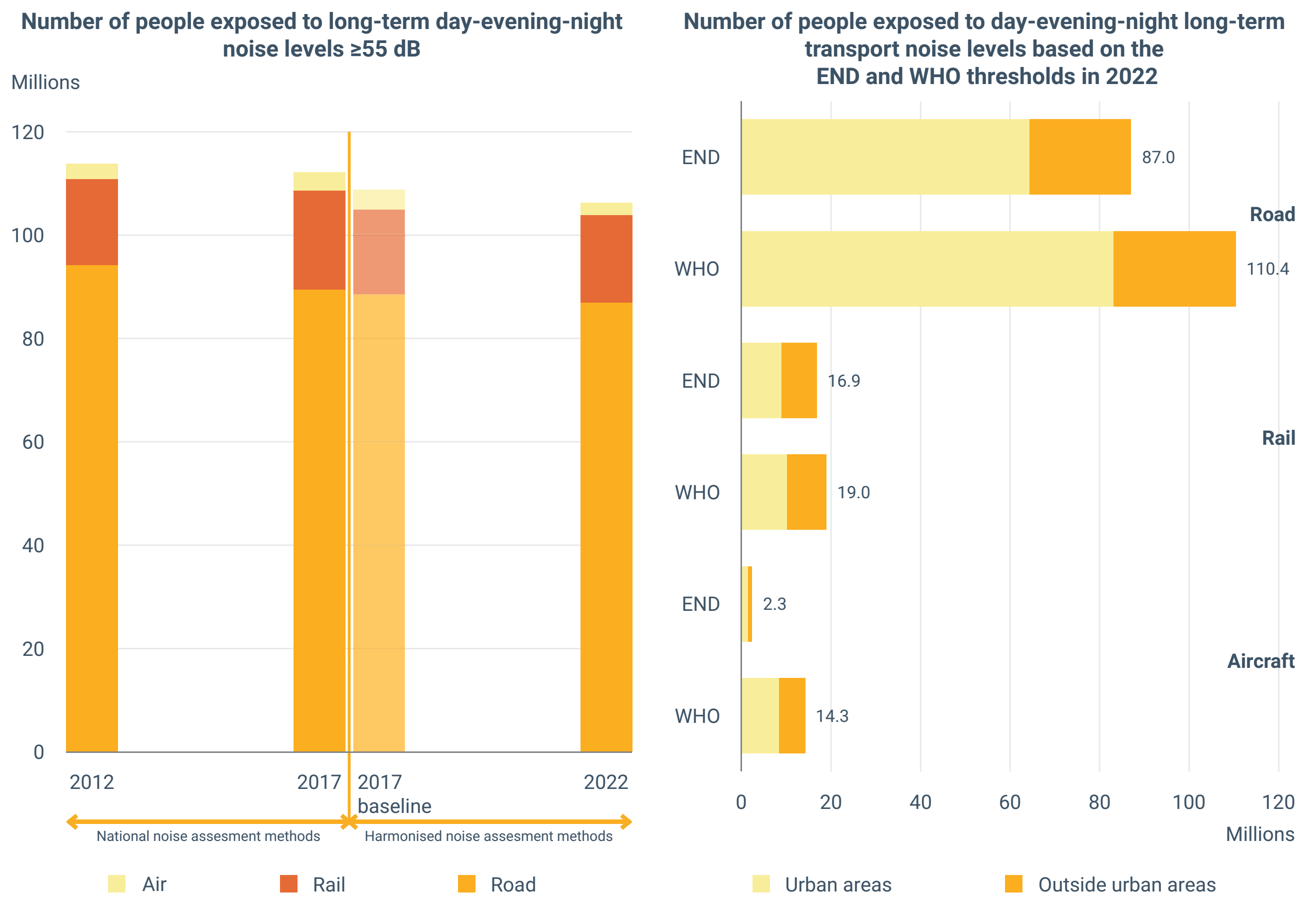
### *4.2.1 Introduction*

Exposure to environmental noise as defined under the Environmental Noise Directive (END) is a widespread problem in Europe: more than 20% of its population is exposed to noise levels considered harmful to health (see indicator 'Exposure of Europe's population to environmental noise') Long-term exposure to noise impacts both physical and mental health. Prolonged exposure above certain levels leads to non-auditory effects like annoyance, sleep disturbance, cardiovascular and metabolic issues as well as cognitive impairment in children (WHO Europe, 2018).

### *4.2.2 Number of people exposed to harmful levels of noise from transport*

Data reported under the END (EEA, 2024g) estimates that in 2017 (the baseline year for the ZPAP target) more than 108 million people in the EU were exposed to harmful levels of air, rail and road traffic noise; that is, above 55dB during the day-evening-night period (Lden). By 2022, this figure was estimated to be approximately 106 million. This suggests a marginal decline in the population affected by harmful noise levels during that period. However, it is challenging to draw definitive conclusions about this trend due to changes in the calculation methodologies employed between these years (see indicator 'Exposure of Europe's population to environmental noise').

**Figure 4.4** **Estimated number of people exposed to unhealthy noise levels, based on END thresholds, in the EU-27**




**Notes:** Based on data submitted under the END where Member States are required to produce strategic noise maps for roads with more than 3 million vehicles per year, railways with more than 30,000 railway movements per year, and airports with more than 50,000 air traffic movements per year in urban areas with more than 100,000 inhabitants. A 2017 baseline (ETC/HE, 2024b), comparable to the 2022 data, has been estimated to assess changes between 2017 and 2022.

**Sources:** Noise data reported under END (EEA, 2024g).

### *4.2.3 Number of European residents chronically disturbed by noise from transport*

Long-term exposure to transport noise can lead to a variety of health issues. While the most common effects include annoyance and sleep disturbances, research also links noise exposure to an increased risk of developing cardiovascular, mental health and metabolic disorders. Emerging evidence suggests connections between traffic noise and additional health outcomes such as cancer, dementia, infertility, respiratory problems, suicide, tinnitus and various forms of mortality (see signal 'The health effects of transport noise and implications for future health risk assessments').

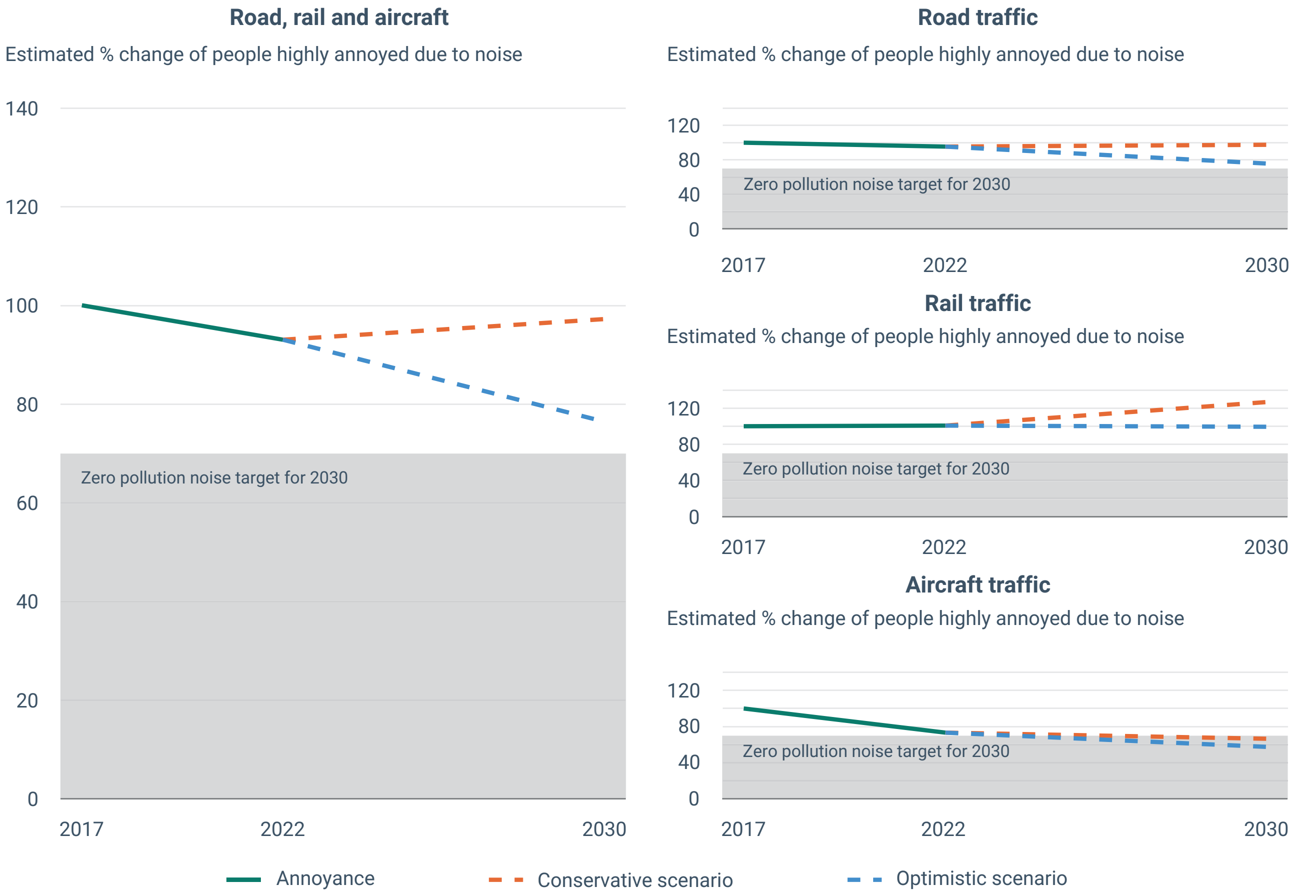
Based on 2022 data, an estimated 16 million people in the EU are highly annoyed due to long-term exposure to transport noise and 4.4 million are severely sleep disturbed for the same reasons. In 2017, these figures were approximately 6% and 6.5% higher, respectively. To meet the zero pollution objective of reducing the number of people chronically disturbed by transport noise by 30% by 2030, the number of people experiencing high levels of sleep disturbance needs to be reduced by 1.4 million and the number of people who are highly annoyed by noise by 5.1 million.

### *4.2.4 Outlook*

Projections indicate that while a decrease in the number of people highly annoyed by noise is anticipated, achieving a reduction of at least 30% in the number of people chronically disturbed by transport noise levels by 2030 is unlikely without additional measures including regulatory or legislative changes. Under an optimistic scenario that includes the implementation of a substantial set of additional measures, the number of people highly annoyed by transport noise is predicted to decline by about 23% by 2030. Under a conservative scenario, this number is predicted to decrease by only 2%.

The large number of people exposed to road traffic noise significantly influences the overall outlook, which indicates that more effort is needed to address road traffic noise. Efforts are also needed to mitigate the negative health impacts from projected growth in rail activity. To achieve greater progress, measures should focus not only on areas with severe noise problems (i.e. hot-spots), but also on areas with moderate noise levels, generally below national limits (EEA, 2022d).

**Figure 4.5 Estimated percentage change in number of people highly annoyed by noise from transport in the EU from 2017 to 2030 under conservative and optimistic scenarios**




**Notes:** In this outlook, progress towards the zero pollution noise target is measured by assessing changes in the number of people highly annoyed by noise from road, rail and aircraft at EU level using data on population exposure collected under the END. High annoyance is considered a good indicator for measuring adverse health effects of noise as it can be a harbinger of more severe health problems. Therefore, this indicator is used as a proxy for chronical disturbance in this outlook.

**Source:** ETC HE, 2024c.

## 4.3 Water pollution and human health

**Key messages**

- In 2023, 85% of EU bathing water sites were rated excellent and 96% met minimum water quality standards.
- Compliance with the Drinking Water Directive (DWD) is reported as being generally high; more data will soon be collected under the new Directive and additional limits will apply to drinking waters.
- Freshwater used for drinking water production needs increased treatment due to the presence of micropollutants, which in turn raises the cost of drinking water.
- The revised Urban Wastewater Treatment Directive (UWWTD) aims to address micro-pollutants and microplastics with new standards, quaternary treatment and monitoring requirements.
- The proportion of the EU population connected to at least secondary wastewater treatment reached 81% in 2022.
- Climate change is intensifying droughts and floods, reducing water quality and quantity, and posing an increasing threat to health. Protecting water resources from the effects of pollution is thus even more critical.

### *4.3.1 Introduction*

Access to clean water is essential for basic needs such as drinking, food preparation, hygiene and sanitation. Water pollution, whether from chemicals, bacteria or nutrients, poses direct health risks through contaminated bathing and drinking water, and indirect risks through contaminated food. The Water Framework Directive (WFD) (EU, 2000) plays a crucial role in setting the overall framework for water management across Europe, ensuring the protection and sustainable use of water resources.
In the EU, drinking water and bathing water are regulated by the DWD (2020b) and Bathing Water Directive (BWD) (EU, 2006a), respectively. To ensure public health and environmental protection, urban wastewater treatment is governed by the UWWTD (EU, 2014), as legislation on water reuse (EU, 2020c) aims to stimulate and facilitate safe water reuse in the EU. This section focuses on the health impacts of water pollution on human health; the pollution risks to freshwater, soil and marine environments will be explored in the ecosystem section (Section 5).

### *4.3.2 Drinking and bathing water*

The objective of the EU DWD is to establish minimum standards for the quality of drinking water to protect public health. Since 1980, various revisions of the DWD have been adopted, setting minimum standards for chemicals and nutrients. Compliance with this Directive is generally very high. However, data are outdated and do not address emerging risks for drinking water.

The 2020 revision has therefore strengthened the previous standards, which now encompass pesticides and emerging pollutants like PFAS, endocrine disruptors (e.g. nonylphenol and beta-oestradiol) and microplastics. In addition, caffeine, certain pharmaceuticals and trifluoroacetic acid also threaten drinking water quality. These substances can penetrate natural and artificial barriers, complicating and increasing the cost of water treatment (EEA, 2024h).

The recast DWD requires the EC to establish technical guidelines for monitoring PFAS, including detection limits, maximum concentration levels and sampling frequency. As traditional water treatment methods are ineffective against PFAS, emerging technologies such as activated carbon absorption, ion exchange resins, and high-pressure membranes like nanofiltration and reverse osmosis are also being developed (Treatment of drinking water to remove PFAS). In addition, the EC has established a methodology for measuring microplastics in drinking water (EC, 2024j) Once the pollutants have been included in the list of substances and compounds of concern (DWD watch list), monitoring shall be undertaken by Member States and, if the guidance values are exceeded, appropriate measures introduced to address the issue. Such precautionary measures have been set up while the health impacts of microplastics are still under investigation (see signal 'Impacts of microplastics on health'). As obligatory monitoring in the EU will only start once microplastics are included in the DWD watch list, there are currently very limited data available on the presence of microplastics in drinking water.

The EU seeks to safeguard high bathing water standards and monitoring across Member States. This involves enhancing public awareness through the improved dissemination of information, adopting comprehensive quality management practices and aligning efforts with broader EU directives aimed at protecting all water bodies. The BWD focuses on monitoring E. coli and intestinal enterococci, bacteria which can cause serious illness in people (EEA, 2024i). These bacteria are important indicators of faecal contamination, which poses a risk to human health due to the potential presence of other pathogens — e.g. viruses such as hepatitis E, salmonella and campylobacter.

Bathing water quality in the EU remains high. In 2023, 85% of bathing waters were rated excellent in the EU and minimum water quality standards were met at 96% of sites (see indicator 'European bathing water quality').

## Box 4.3

**PFAS**

Per-and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals that have become widely known for their persistence and widespread presence in humans, animals, food and the environment, earning them the label 'forever chemicals'. They are commonly used in a variety of products such as building and consumer products, textiles (see Hazardous waste in Section 3.6), medicines and pesticides, vehicles and energy production; this is due to their desirable technical properties, such as resistance to moisture, heat and stains (EEA, 2022e).

PFAS have been detected in groundwater, rainwater, surface water, soils and wildlife including marine organisms (see PFAS in European waters in Section 5.2 and Contaminants in marine organisms in Section 5.3). The majority of well-studied PFAS are considered moderately to highly toxic, showing adverse health impacts on humans and animals including asthma, diabetes, cancer, cardiovascular risks and infectious diseases.

**PFAS (cont.)**

Emissions of PFAS occur throughout the life cycles of products, from production and manufacturing to use and waste management. Large-scale environmental pollution has been found around PFAS production and manufacturing plants in Europe (see signal 'PFAS contamination and soil remediation'). Additionally, PFAS pollution can result from industrial waste sites, incineration of PFAS products and PFAS-based firefighting foams.

People can be exposed to PFAS through various sources including products such as textiles, food and contaminated water, industrial production processes and food packaging. Workers in PFAS-producing plants and specific manufacturing are at higher risk. The Human Biomonitoring for EU (HBM4EU) project found PFAS in the blood of all teenagers sampled across Europe, primarily caused by banned but highly persistent substances (see signal 'Risks of PFAS for human health in Europe')

PFAS are regulated at the global level under the Stockholm Convention, with a broader range of restrictions in place at EU level under the POPs Regulation (EU, 2024h) and REACH (EU, 2006b) (ECHA, 2022). The EU's Chemicals Strategy for Sustainability recommends avoiding non-essential uses of PFAS and calls for the restriction of PFAS as a group of chemicals.

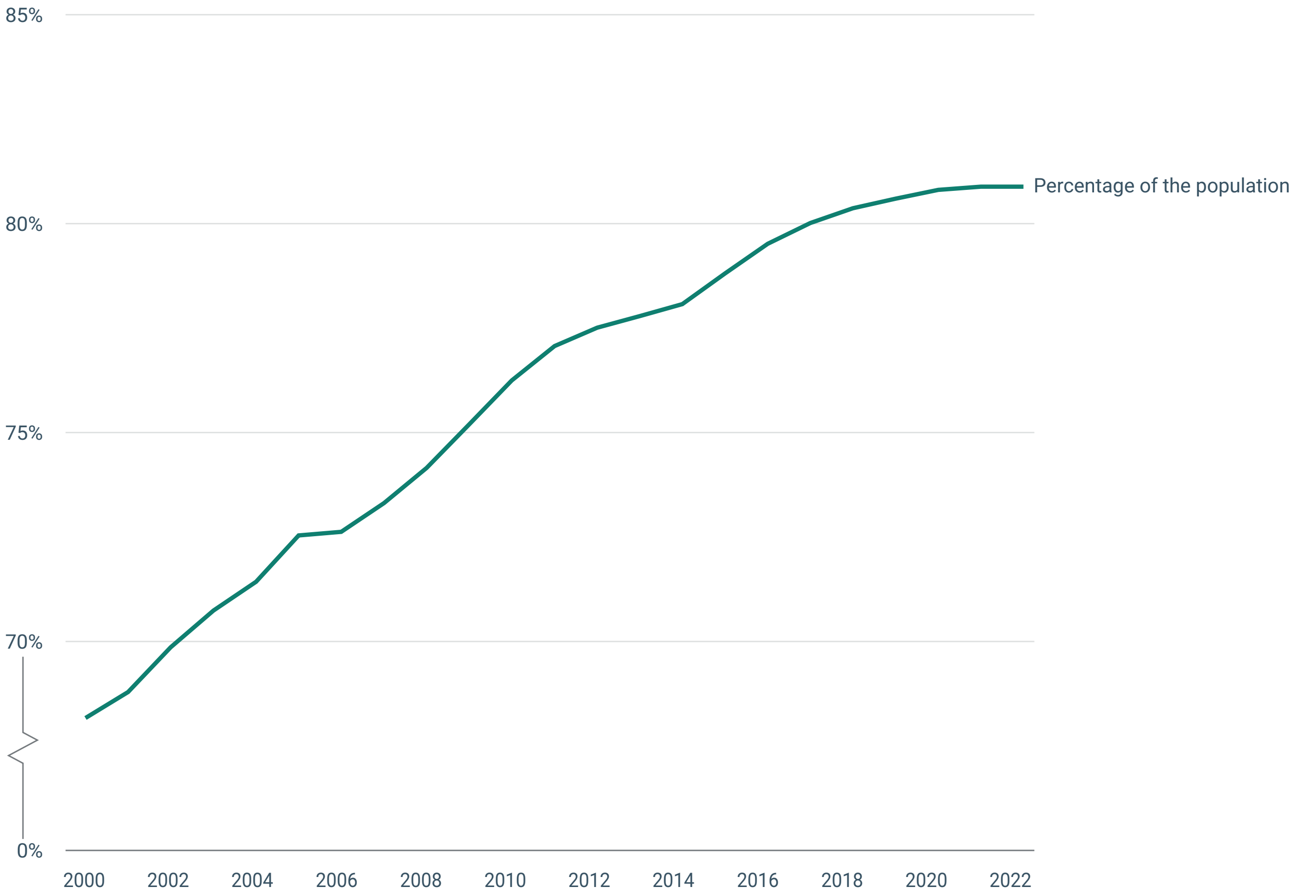
The European Chemicals Agency (ECHA) has prepared a proposal to ban all PFAS from firefighting foams and some Member States are working on a proposal to ban PFAS in other use cases across the EU. The EU has also set limits for groups of PFAS under the 2020 DWD and proposed to include PFAS in the lists of water pollutants to be controlled in surface waters and groundwater.

The recast DWD mandates that the total of PFAS in drinking water should not exceed 0.5μg/l and sets individual PFAS at 0.1μg/l (EU, 2020b). These limit values are currently under review to take account of new evidence. Member States are required to take necessary measures to ensure compliance. However, there are numerous technical and economic challenges that must be addressed before PFAS removal techniques for drinking water can be widely implemented (see signal 'Treatment of drinking water to remove PFAS').

### *4.3.3 Urban wastewater*

Untreated urban wastewater poses significant health risks, as it contains organic matter, nitrogen and phosphorus as well as bacteria, viruses, metals, organics and other chemicals (including pharmaceuticals). These contaminants can lead to waterborne diseases, harmful algal blooms and exposure to toxic chemicals, affecting drinking and recreational water. The UWWTD mandates proper treatment to remove these substances, ensuring water safety and protecting public health by preventing disease outbreaks and maintaining clean water bodies. Since 2000, the EU has made consistent progress in expanding its wastewater treatment coverage. The proportion of the EU population connected to at least secondary wastewater treatment, which means a biological treatment process designed to reduce the amount of organic materials, reached 81% in 2022 (Figure 4.6) (see indicator 'Population connected to at least secondary wastewater treatment').

**Figure 4.6** **Population connected to wastewater treatment at least at the secondary level in the EU-27, 2000-2022**




**Sources:** Eurostat, 2024d.

However, despite these improvements, various emerging contaminants released from treatment plants like antibiotics, microplastics and preservatives pose ongoing risks to both human health and the environment. The revised UWWTD (EC, 2022c or EU, 2024i) aims to tackle micro-pollutants and microplastics in the treatment of wastewater by introducing new standards and monitoring requirements. The concept of quaternary treatment is introduced in the proposal to eliminate the broadest possible spectrum of micropollutants. This would decrease the occurrence of substances of concern in effluents from wastewater treatment plants and hence reduce the cumulative toxicity by about a half (Pistocchi et al., 2022). Furthermore, key health-related parameters will be regularly monitored in urban wastewater, including antimicrobial-resistant microorganisms (see Box 4.4), SARS-CoV-2, the virus causing COVID-19 and other health related threats to enhance pandemic preparedness (EC, 2024k). Another important provision of the revision proposal concerns the obligation for larger agglomerations to adopt integrated urban water management plans aimed at controlling pollution from stormwater overflows. This is to release no more than 2% of the annual dry-weather wastewater load generated in the agglomeration (Quaranta et al., 2022).

## Box 4.4

**Antimicrobial resistance (AMR)**

AMR is a critical global health concern driven by the misuse and overuse of antimicrobials in human medicine, agriculture and animal husbandry. It poses significant public health and economic threats, impacting the effectiveness of treatments, increasing healthcare costs and undermining medical advancements.

The EU has implemented comprehensive policies and regulations to address AMR, aiming to make the region a best-practice leader and shape global standards. However, the global dimension of AMR presents challenges, as resistant strains can rapidly spread across continents (EEA, 2022f). To address this global challenge, the Political Declaration on AMR was presented at the United Nations General Assembly (UNGA) on 26 September 2024 (EC, 2024l) where UN member countries, including EU Member States, committed to concrete actions to address AMR across all sectors through a One Health approach that acknowledges the interconnectedness of human, animal and environmental health.

In Europe, despite a decrease in the consumption of antibiotics, levels of antibiotic resistance in bacteria remain high, leading to significant human health and economic costs. Water bodies play a crucial role in the emergence and spread of AMR. Antimicrobial residues and resistance genes enter aquatic systems through wastewater and agriculture run-off, contributing to the spreading of AMR among microbial communities. Wastewater treatment plants are one of the key focuses in addressing AMR, as they can significantly reduce antibiotic-resistant bacteria and gene levels; however, some resistance genes may persist or increase in treated water and treated sewage sludge can act as a reservoir of AMR, impacting soil when applied to farmland.

Despite the threat posed by AMR, there is currently no legal obligation in the EU to monitor and remove antimicrobial residues or resistance genes. However, the issue is being addressed in the ongoing legislative revision of the Environmental Quality Standards and Groundwater Directives (proposal to revise the Surface and Groundwater pollutants) and the recently-agreed UWWTD. The specific concentrations of antimicrobials and environmental conditions that may contribute to accelerating the emergence of AMR are not completely understood but proposed 'safe' target concentrations have been exceeded in some European rivers.

Monitoring across the EU has presented a mixed picture, with some countries making significant progress in reducing antimicrobial use in livestock and enhancing infection control, while others are facing challenges. The European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) network provides valuable data on veterinary antimicrobial consumption (see Overall EU sales of antimicrobials for farmed animals and in aquaculture in Section 4.5), while the European Antimicrobial Resistance Surveillance Network (EARS-Net) offers insights into human medicine. A pilot survey was launched in 2023 by the European Environment Information and Observation Network (EIONET), in collaboration with the EEA and the European Topic Centre Biodiversity and Ecosystems (ETC BE), to establish a data reporting system in response to the requirement for monitoring AMR genes as proposed in the legislative revision of the Surface and Groundwater pollutants (EC, 2022d).

The EU's outlook for AMR control is cautiously optimistic, with continued efforts to strengthen regulations, promote research and engage in global partnerships. Achieving the ambitious targets set forth in the ZPAP will require sustained international cooperation. International initiatives, such as the AMR Roadmap of Action, aim to prevent the emergence and spread of AMR and provide innovative treatment options.

#### 4.3.4 Waste-related impacts of climate change on human health

Climate change is causing increasing concern around water quality. More frequent droughts can indirectly alter water quality in rivers, when low flow leads to increased pollutant concentrations, or in lakes by decreasing the water level via increasing evaporation and lower river inflows (EEA, 2024g).

Whilst the implementation of the existing legislation has led to improvements in water quality, ongoing climatic changes pose additional challenges. The EEA report '*Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality*' highlights water-related impacts of climate change on health and well-being that are already observed across Europe — leading to deaths, injuries, mental health consequences and outbreaks of infectious diseases.

Flooding can result in contamination of water supplies and also soils, for example with pathogens related to sewage or from chemicals mobilised from sediments. Currently, one in eight Europeans lives in areas prone to river floods and 30% of southern Europeans live in areas with permanent water stress. Climate change will exacerbate these issues, increasing exposure to extreme weather and health risks. Vulnerable groups specifically affected here include senior citizens, children, those in poor health, lower-income individuals, farmers and emergency service workers.

The escalating threats associated with climate change further emphasise the importance of protecting water resources from pollution risks to increase population resilience and support adaptation to the effects of climate change.

## Box 4.5

**Microplastics**

Microplastics are small, plastic particles generally less than 5mm in size. They are made of synthetic polymers (e.g. polyethylene, polypropylene, polyvinyl chloride (PVC), polyethylene terephthalate (PET)) or chemically modified natural polymers (e.g. nitrocellulose) and can take different shapes such as roundish or irregular particles as well as films and fibres.

Microplastics can be intentionally produced (so-called primary microplastics), such as plastic pellets used in industrial manufacturing or particles added to products for a specific purpose, for example as exfoliates in cosmetic products. Furthermore, they can be formed through the breakdown of larger plastic items during their lifecycle (secondary microplastics); for example, by tyre abrasion, fibres released from synthetic cloth or the degradation of plastic articles ending up in the environment due to improper waste management. The main sources of emissions of secondary microplastics in the EU are paints, tyres, pre-production pellets, artificial turfs and textiles (EC, 2023j). Primary microplastics are much less abundant in the environment than secondary microplastics.

Microplastics end up in the air, soil and water and can stay there for long periods. Depending on the particles' properties and environmental conditions, microplastics can be carried from the environment to which they have been released. Typical distribution pathways are microplastic-containing road dust resuspension, deposition of airborne particles to water and soil, and the capturing of microplastics into sewage sludge during wastewater treatment, with subsequent application to agricultural land. Microplastics can travel long distances, leading to their presence even in remote regions such as the Arctic.

**Microplastics (cont.)**

Microplastics have been shown to have adverse effects on biota when ingested (GESAMP, 2016) and they can be transferred to humans via the food chain (Lusher et al., 2017). Some studies have linked microplastic exposure with negative health effects in humans (see signal 'Impacts of microplastics on health') but significant knowledge gaps remain. It is certain that people are exposed to microplastics and thus can inhale them from the air or ingest them via food. It is not yet known which characteristics of microplastic particles may cause adverse effects. There is also concern that these particles may carry harmful substances such as additives and residual monomers or agents adsorbed to the particles' surface — for example, persistent organic pollutants, heavy metals and microorganisms.

Reducing the release of microplastics is imperative to protect the environment and avoid potential risks to human health. The EU has responded to this pollution challenge through key policy documents like the Plastics Strategy (EU, 2018) and the ZPAP (EC, 2021a), one of the targets of which is to reduce microplastic releases by 30% by 2030 (see Section 5.3 for target analysis). To achieve this target, three approaches are being pursued in the EU: (i) reducing pollution from plastic products, as they degrade into microplastics; (ii) restricting the use of intentionally added microplastics in products; and (iii) reducing the unintentional release of microplastics. To date, several measures have been adopted, such as a ban on certain single-use plastics (EU, 2019a), a restriction of intentionally produced microplastics (EC, 2023d) and a legislative proposal put forward on preventing pre-production pellet loss (EC, 2023b). To complement these initiatives, monitoring methodologies and requirements were introduced, e.g. for marine water (EU, 2017a) and drinking water (EU, 2020b). Alternately, they will be introduced for e.g. wastewater and sludge (EC, 2022c) or in surface and groundwaters through the ongoing review of the water pollutants (EC, 2022d). Additionally, regulatory measures are being considered for e.g. groundwater, tyres, textiles, washing machines and more. Such measures need time to take effect.

## 4.4 Soil pollution and human health

### Key messages

- Currently, 60-70% of soils in the EU are unhealthy, reducing their ability to provide essential services and posing risks to human health, the environment, food security, climate, economy and society.
- Soil is a key pathway for contaminants to enter the human body. Its capacity to filter polluting substances after transport through air and water is limited and, for some substances, already exceeded.
- Soil pollution is linked with an array of health effects such as cancer, cardiovascular diseases and mental health disorders.
- The current knowledge base about soil pollution's health impact is still limited. However, EU investment in the Soil Mission and the new Soil Monitoring Law are expected to provide greater insights by 2030.

### 4.4.1 Introduction

Healthy soils are crucial for our economy, society and environment as they produce food; enhance resilience to climate change, extreme weather, drought and floods; and support our well-being. Currently, 60-70% of soils in the EU are unhealthy (EC, 2023g). This includes an extensive set of historic pollution (brownfields) as well as the impact of current polluting activities including waste, industry, mining, certain agricultural practices and others. Soils have the capacity to filter substances, thereby protecting crops, water quality and human health and provide the physical grounds for many human activities (EC, 2023g). Contaminated soils affect food safety; 21% of EU agricultural soils, for example, have high cadmium levels (EC, 2023g) as well as copper and zinc levels that exceed limits (see also section 5.4 Soil pollution and ecosystems).

The first ZPMA report states that the number of potentially contaminated sites across the EU is high, yet likely underestimated. Over 50% of sites are unregistered or not risk assessed. While recent trends in managing contaminated sites are positive, national actions vary significantly across the EU and the rate at which contaminated sites are being remediated still needs to increase. For example, 70% of all potentially contaminated sites are registered in only two countries due to their very advanced national legislation and registers (EEA, 2022g). The large number of undetected or suspected contaminated sites creates substantial uncertainty as to the risk to citizens and the environment (EEA, 2022a).

Legislative measures to maintain and improve soil health are not as well developed as for other media. The proposed SML suggests measures to improve the monitoring and assessment of soil contamination and to enhance the identification, investigation, risk assessment and remediation of contaminated sites. The SML approaches point source pollution (contaminated sites) and diffuse pollution differently but applies a risk-based approach for both.

### 4.4.2 Heavy metals and pesticides in soils, and their health impacts

Soil pollution in the EU is poorly quantified compared to pollution in other media such as air and water. Consequently, the limited research linking soil contamination to human health relies on case studies from specific local populations, tackling merely a subset of contaminants – specifically, metals and pesticides – within the broader spectrum of soil pollutants found in the EU (Vieira et al., 2024).

Various studies have highlighted the connection between soil pollution and human health in the EU. For instance, a higher concentration of metals and metalloids in soil is associated with all-cause cardiovascular diseases mortality, some types of cancer and an increased probability of mental disorders (Ayuso-Álvarez et al., 2019; Núñez et al., 2017). Higher rates of lung cancer mortality were observed in regions with high concentrations of arsenic or cadmium in soil when compared to regions with lower concentrations (Bartnicka et al., 2023). A higher carcinogenic risk due to soil pollution by arsenic and lead in some locations was supported by the observation of increased regional standardised mortality rates, due to cancers normally associated with these pollutants (SOLACE).

There are comprehensive EU-wide studies on the presence of heavy metals (arsenic, cadmium, copper, mercury and zinc) in topsoil. However, further ecotoxicological assessment, specifically regarding the risks to human health, is lacking. Following the significant investment from the EU in the Soil Mission and the perspective offered by the new SML proposal, it is expected that more insights will be gained by 2030.

## 4.5 Chemical pollution and human health

### Key messages

- Human biomonitoring data highlight the health risks of exposure to several substances, including metals (arsenic, cadmium, chromium, lead and mercury), bisphenol-A and certain PFAS.
- A comparison between the periods 2007-2014 and 2014-2021 shows a decreasing trend in the overall health risk associated with the combined exposure to 15 substances prioritised for human biomonitoring. The decrease seen with recently-regulated substances (e.g. perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), phthalates) proves the effectiveness of regulatory interventions.
- More efforts are needed to control exposure to persistent organic substances and metals, and to ensure that restricted substances are replaced by safe and sustainable alternatives.
- By 2022, the use and risk of chemical pesticides and the use of more hazardous pesticides (in quantitative terms) decreased by 46% and by 25%, respectively. However, further action is needed to reach a 50% reduction. Considering the limits of current indicators, risk-based indicators currently under development will be essential to better estimate risks and trends.
- In 2022, the overall sales of veterinary antimicrobials for farmed and aquaculture animals decreased in the EU by 28% compared to 2018, achieving more than half of the 50% reduction target set by the ZPAP.

### *4.5.1 Introduction*

Exposure to chemical pollution is associated with a range of health consequences, including chronic diseases, neurological disorders, immunotoxic effects, genetic damage and disruptions to the endocrine system affecting development and fertility (EEA, 2022a). The WHO estimated that 1.6 million deaths in 2016 were linked to exposure to specific chemicals (WHO, 2023b). The top 10 chemicals of global public health concern identified by the WHO include heavy metals (arsenic, cadmium, lead and mercury), air pollutants and highly hazardous pesticides. In the EU, the ECHA has compiled a candidate list of substances of very high concern for authorisation; this currently includes 241 substances, many of which are included on the list due to health concerns.

In Europe, there is significant production and consumption of various chemicals known to be harmful to human health. People are regularly exposed, in varying concentrations, to complex mixtures of these chemicals through the consumption of contaminated food and drinking water, inhalation of polluted air and dust, occupational activities and the use of everyday consumer items (EEA, 2022a). An analysis of production and consumption by hazard class shows that the share of all chemicals hazardous to health in the EU's total chemicals production has slightly decreased — from approximately 78% in 2004 to its lowest level of 77% in 2023. The production of carcinogenic, mutagenic and reprotoxic (CMR) chemicals, which are the most hazardous, showed little change between 2004 and 2007, fluctuating between 42 million and 44 million tonnes. In 2023, CMR chemical production was 36 million tonnes. The share of CMR chemicals in total EU chemical production has varied between 13% and 15% since 2004 (see indicator 'Growth of the EU chemicals market for substances of different levels of concern').

Risk management interventions implemented by chemical legislation (e.g. REACH) are a major drive to control the production, import and use of substances of concern. The CSS brought forward several initiatives to accelerate the move towards safer chemicals. The SSbD framework supports industry to identify safer chemicals from the innovation stage. Initiatives aimed at improving efficiency under the 'one substance, one assessment' package enhance and expedite regulatory processes via the better sharing of data and assessments (EC, 2023k). Among these is the establishment of an EU Early Warning System for emerging chemical risks, which aims to ensure faster identification and a shorter response time by authorities.

Human biomonitoring is currently performed under the EU-funded research partnership PARC and is a powerful tool for assessing the real-life exposure of substances of concern in humans. Substances are prioritised for biomonitoring based on the level of health concern and current policy needs. For example, in a previous research programme, HBM4EU, chemicals from 17 substance groups were measured in humans, including metals (arsenic, cadmium, chromium, lead and mercury), pesticides, phthalates, polycyclic aromatic hydrocarbons (PAHs), PFAS and bisphenols.

This section looks at some of the most important chemical pollutants for human health, such as metals, pesticides and bisphenol A (BPA). Other health-relevant pollutants are featured in other parts of the report, e.g. particulate matter (Section 4.1 Air pollution and human health) as well as PFAS and AMR (Section 4.3 Water pollution and human health).

### *4.5.2 Metals*

Cadmium, chromium VI, inorganic arsenic, lead and mercury are toxic substances with serious health risks and are extensively regulated in the EU.

Mercury is a neurotoxin that affects the digestive, immune and nervous systems, as well as the eyes, kidneys, lungs and skin. It also has detrimental effects on foetal and early childhood growth, with extensive evidence of adverse effects on neural development. Mercury can travel over long distances before being deposited on land and water. It cannot be degraded and therefore builds up in soil, water and living organisms. Humans are exposed to mercury via the inhalation and ingestion of mercury released from dental amalgam restorations. Other exposure routes include the ingestion of contaminated fish or occupational exposure during fluorescent lamp production, gold mining, mercury battery production and recycling. Human biomonitoring shows that pregnant women in the EU whose diet includes specific fish and seafood are still exposed to mercury and in some cases, their exposure exceeds the EFSA's health-based guidance value indicating a potential risk (HBM4EU, 2022a).

Reflecting the global dimension of the problem, the Minamata Convention on Mercury was signed in 2013, addressing several of the activities responsible for significant mercury releases into the environment. The EU has implemented several policies to tackle mercury with the aim of controlling, eliminating and (where this is not feasible) reducing use and exposure to mercury. The most recent is the revision of Regulation (EU) 2017/852 (EU, 2017b), which addresses the whole life cycle of mercury from primary mining to its final disposal as waste. The Regulation prohibits additional mercury-added products, including the use of dental amalgam, as of 1 January 2025 (HBM4EU, 2022a).

Lead exerts toxicity in several organs and systems in humans. Its neurodevelopmental effects are particularly concerning, with foetuses and children being the most sensitive groups. Exposure occurs mainly through diet, but also from drinking water, tobacco smoke, contaminated household dust and particles originating from burning waste. Concentrations in blood show a decreasing trend in recent decades due to regulations and recently levelled out at concentrations below the reference values set by different organisations. Whereas exposure to lead in Europe is expected to decrease due to regulatory interventions, global consumption is expected to rise, mainly due to the increasing demand for batteries for electric vehicles (HBM4EU, 2022b).

Cadmium primarily accumulates in the kidneys, potentially leading to renal failure, and is classified as a human carcinogen, reproductive toxin and suspected mutagen. The general population is mainly exposed to cadmium through food, with additional risks from smoking. Occupational exposure, particularly in industries involving metal work and pigments, can be significant. Human biomonitoring under HBM4EU has shown that a portion of the European population has cadmium levels that pose a risk of adverse kidney effects, especially in western and eastern Europe (HBM4EU, 2022c). Regulations under REACH cover its use in cadmium plating, jewellery, paint, plastics and various consumer products like batteries and toys.

Chromium VI's primary health concern is its carcinogenicity, with increased risks for lung, nasal and sinus cancers among workers in industries like stainless-steel welding and surface coating. The general population can be exposed through contaminated food, air and consumer products. Although its use in many sectors requires authorisation under REACH, it is banned or restricted in items such as cement, cosmetics, leather, preserved wood and toys (HBM4EU, 2022c). Biomonitoring has revealed elevated levels of chromium VI in workers in certain industries.

Inorganic arsenic from both natural and anthropogenic sources poses a global health threat, particularly through the contamination of drinking water and soil. Long-term exposure has been linked to cancer, cardiovascular diseases, diabetes, negative effects on brain development and skin lesions (WHO, 2022). Despite regulations on arsenic exposure in the EU, including drinking water limits and REACH restrictions, biomonitoring studies suggest that a large fraction of the EU population may be at risk due to high arsenic levels (HBM4EU, 2022d).

### *4.5.3 Pesticides*

Exposure to pesticides has been associated with carcinogenic, endocrine, neurological, respiratory and reproductive effects, among others (Nicolopoulou-Stamati et al., 2016). Diet is the main source of pesticide exposure for the general population. Human exposure also occurs occupationally and via indirect environmental exposure. A wide range of pesticides, some with hazard-relevant classifications for humans, have been detected in homes near agricultural fields in ten European countries (Silva et al., 2023).

Concerning dietary exposure, a recent EFSA study found that 97.9% of sampled food products met legal limits for pesticide residues, indicating compliance with regulatory standards established to protect human health. The signal 'Pesticides in food' uses data collected under EU and national food programmes screening for pesticides residues. Generally, the signal confirms a low exposure to pesticides via food and, importantly, shows a decreasing trend in residual risk between 2011 and 2020. This positive development suggests that strategies to reduce pesticide risk have been effective in also reducing risk to human health.

The JRC developed an indicator for assessing non-dietary risk in individuals due to exposure to pesticides from living in proximity to agricultural areas. Monitoring such risks requires spatially-localised pesticide use data, which are currently not available. For that reason, the indicator has been built by using the granular sales data which are publicly available for France. The results revealed that 13% of the French population might be exposed to pesticides, with 74% obtaining exposure in the lower to middle range and 26% in the higher range. The most relevant crops, which account for a higher proportion of the risk, are potatoes, spring barley, sugar beets and grapevines (Galimberti et al., 2024).

Human biomonitoring could provide an improved picture of combined dietary and non-dietary pesticide exposure in humans, but the current scope is limited to a very small number of these chemicals. Evidence of non-dietary exposure to pesticides is incomplete, making it challenging to derive meaningful indicators.

© Hugo Ferreira, Urban treasures/EEA

## Box 4.6

**EU trends in the use and risk of chemical pesticides, and use of more hazardous pesticides**

Monitoring trends in the use and risk of chemical pesticides is crucial for designing effective policies and monitoring progress towards objectives. The ZPAP aims to achieve a 50% reduction in the use and risk of chemical pesticides and the use of more hazardous pesticides by 2030.

The EC publishes updated progress towards farm to fork (F2F) pesticide reduction targets for the period 2011-2022. By 2022, according to these indicators, the use and risk from chemical pesticides has dropped by 46% and the use of more hazardous pesticides decreased by 25% compared to the baseline period of 2015-2017 (Figure 4.7).

It is important to note that the methodology of harmonised risk indicators (HRI) on which these indicators are build is simplistic and has been criticised, among others, by the European Court of Auditors (ECA, 2020). The lack of appropriate data on pesticide use, however, limits our knowledge about the exposure of humans (operators, local residents and the general population) and the environment. Similarly, the environmental concentrations and impacts (e.g. in water or on pollinators) are still high and there is no sign of a decrease.

**Potential actions**

Looking ahead, the data scarcity issue will be partially addressed by the Statistics on Agricultural Input and Output Regulation (EU, 2022b), starting from 2025, Eurostat will publish sales data of individual active substances annually. Member States will also report pesticide use statistics for a set of most common crops for the year 2026. Additionally, from 2026, users of plant protection products will be required to record all pesticide uses electronically, enabling national authorities to use this data for improved monitoring and risk reduction strategies. These changes in data availability have the potential to allow for more precise on-site risk calculations and to understand the precise pesticide quantities and trends, as well as the types of pesticides released into the environment.

Improved risk-based indicators have been developed for soil, based on LUCAS soil monitoring data, and other developments are explored for human and environmental exposures. Integrating these improved indicators in policy evaluation frameworks will provide more robust scientific evidence to monitor progress against targets.

Multiple policy and environmental factors will determine future trends of pesticide use and risk. The EU's strict regulatory framework on pesticides has been effective in removing the most problematic substances from the market based on identified risks to human health and the environment. The lack of consideration for mixtures in regulatory assessments, however, remains a concerning gap.

**Figure 4.7** **Use and risk of chemical pesticides (upper) and use of more hazardous pesticides (lower) in the EU-27, 2011-2022**


**Source:** Use and risk of chemical pesticides and Use of more hazardous pesticides, Eurostat.

### *4.5.4 Bisphenols*

Bisphenols are used to produce polymers and resins for plastic materials. Due to its widespread use and hazardous properties, Bisphenol A (BPA) has been extensively studied. The tolerable daily intake (TDI) threshold of BPA was recently lowered by the European Food Safety Authority (EFSA) by a factor of 20,000 based on evidence that BPA affects the immune system. In addition, BPA is an endocrine disruptor that can impact the hormone system's normal functioning. It can affect cognitive function, mammary gland development, metabolism and reproductive function (EEA, 2023g).

Test results show that concentrations in urine exceed safety limits in 92% of the general population of 11 European countries (EEA, 2023g). EU and national authorities implemented various measures to restrict the use of BPA, including a new proposal on the restriction of BPA and other bisphenols in food contact materials including plastic and coated packaging. Other bisphenols used to replace BPA (e.g. bisphenol S) have raised similar health concerns. Therefore, they are being monitored, assessed and regulated to minimise regrettable substitutions.

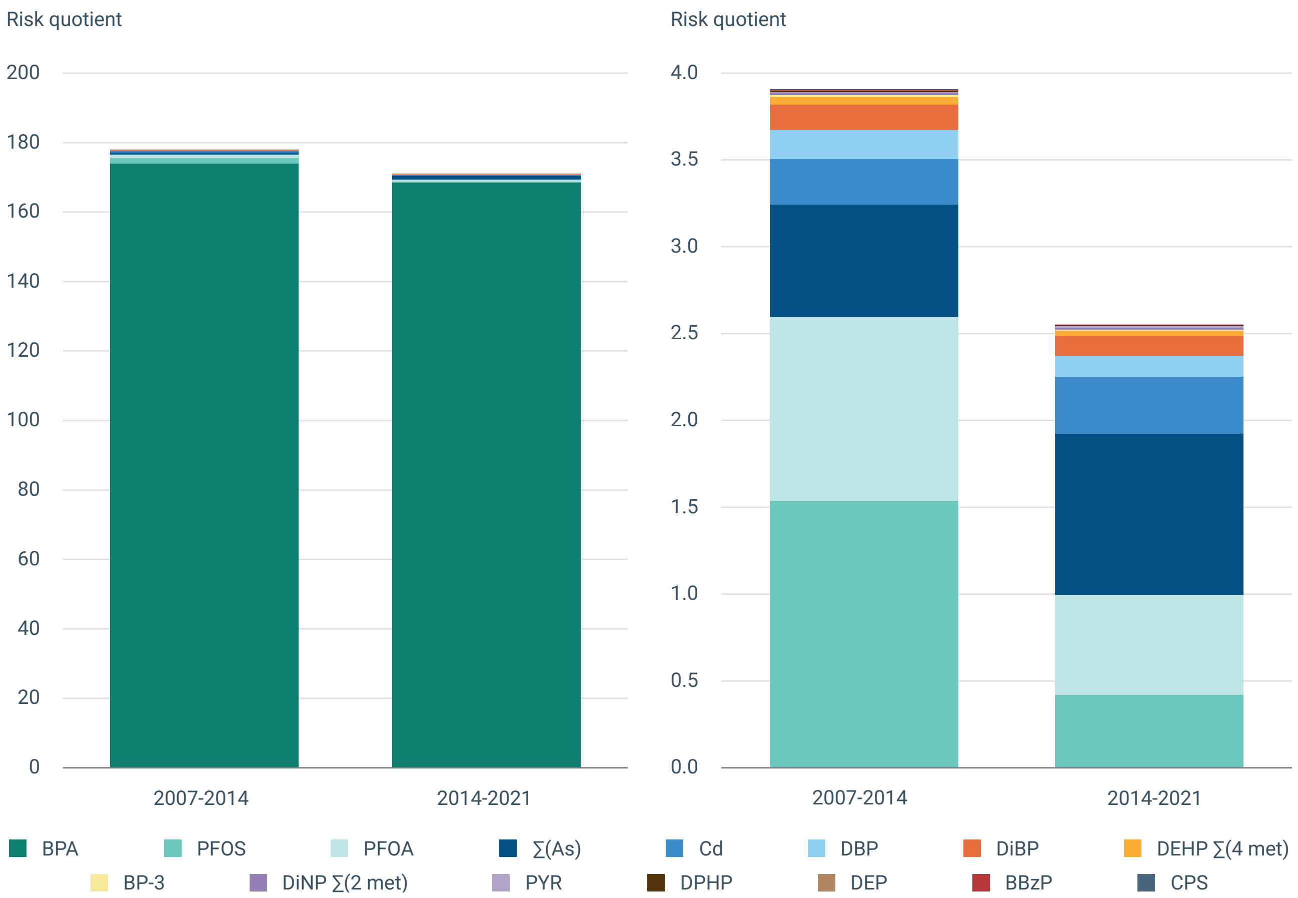
Data from the EU indicator framework for chemicals signal on bisphenol A exposure in adults indicate a decreasing trend in BPA levels in urine from 2014-2021. Despite this decrease, BPA exposure remains above safe levels, emphasising the need to further reduce exposure.

### *4.5.5 Risks from human exposure to chemical mixtures*

Humans are exposed to complex mixtures of environmental chemicals. Human biomonitoring surveys provide human internal exposure data for multiple substances; data from the 2014-2021 survey indicate a potential health risk from exposure to a combination of 15 substances (or groups of substances) (see signal 'Risks of chemical mixtures for human health in Europe'). Seven of these substances drive the risk: BPA, the perfluorinated chemicals PFOS and PFOA, arsenic, cadmium and two phthalates (monobutyl phthalate and monoisobutyl phthalate). Monitoring results indicate a decrease in the overall human health risks in the EU between the periods 2007-2014 and 2014-2021. The trend is driven by the decreasing concentrations of PFOS, PFOA, monobutyl phthalate and monoisobutyl phthalate.

PFOA and PFOS were the two long-chain PFAS of highest concern and were therefore the first PFAS to be assessed and regulated. Health concerns and regulatory scrutiny have now broadened to many more PFAS. Some of these have been prioritised for biomonitoring.

**Figure 4.8 Risk of a mixture of 15 substances prioritised for human biomonitoring in the European population in the periods 2007-2014 and 2014-2021**




**Notes:** Human biomonitoring was undertaken to detect the biomarkers of 15 prioritised substances. The graph on the right indicates the risk quotients for 14 substances, excluding BPA, and serves to better illustrate the mixture risk. PYR does not refer to a substance but to a group of pyrethroid insecticides. Other substance abbreviations and their corresponding biomarkers are described in the table associated with this signal.

**Sources:** IPCHEM dataset 2007-2014, JRC and IPCHEM dataset 2014-2021, JRC.

The substantial decrease of phthalates of highest concern is a positive signal. Continuous monitoring and assessment of alternatives used as replacement will be essential to confirm the effectiveness of restrictions and to avoid regrettable substitutions.

Concentrations of other substances of concern, however, are constant or even slightly increasing. Despite uncertainties, results indicate some success in risk management interventions as well as need for further action. Analysis is limited to those substances that have been prioritised for human biomonitoring, with sufficient data covering both periods and with established HBM health-based guidance values.

### *4.5.6 Occupational exposure*

The EU's second CEAP is expected to significantly impact employment in the waste sector. However, there is limited research on working conditions in waste management or the broader circular economy. According to the European Agency for Safety and Health at Work (EU-OSHA), workers in this sector may be exposed to substances causing health issues such as acute toxicity, allergies, cancer, infections and respiratory problems.

For example, workers handling and recycling WEEE are exposed to hazardous substances such as flame retardants, heavy metals (e.g. cadmium, chromium VI, cobalt, lead and nickel), phthalates (e.g. Di-'isononyl' phthalate), polychlorinated biphenyls (PCBs) and other chemicals. This exposure can lead to adverse health impacts, especially in facilities with inadequate protective measures. Research shows elevated levels of heavy metals and organic pollutants among those exposed to WEEE, increasing health risks such as hormonal disruption and impacts on neonatal growth. Additionally, almost half of WEEE does not reach appropriate treatment plants but ends up in metals scrap and residual waste, is illegally exported or is simply unaccounted for, posing high risks to workers handling such waste without proper precautions (see signal 'Occupational exposure in recycling facilities').

The Worker's Exposure Survey on Cancer Risk Factors, coordinated by EU-OSHA, has estimated the current prevalence and levels of exposure of workers to known carcinogens in all sectors of activity, including in waste and nuclear waste management, across six EU countries (EU-OSHA, 2024). It will also provide valuable information on the availability and use of preventive measures reported by workers in the workplace.

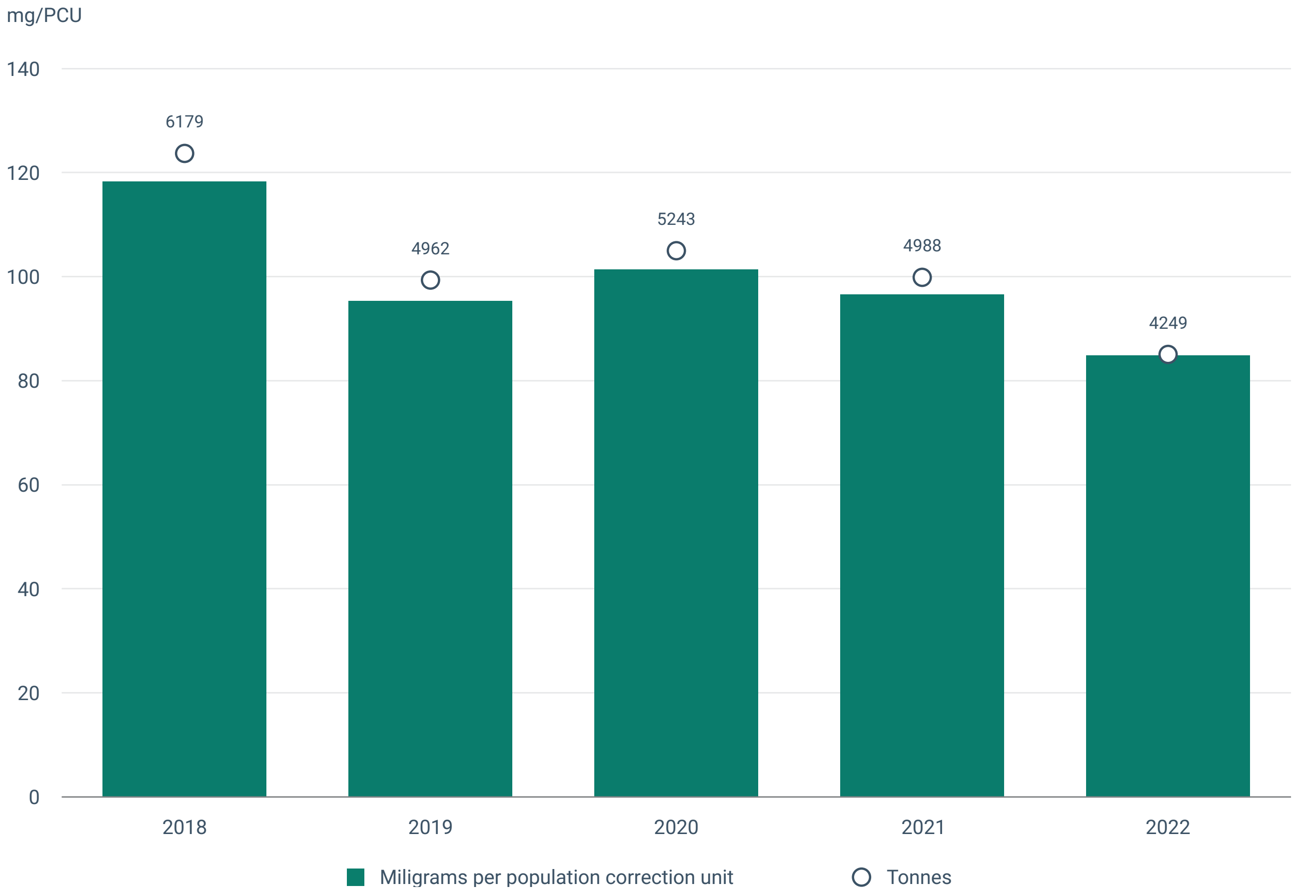
As such, while projects like HBM4EU have explored occupational chemical risks, there is insufficient data on the exposure of workers in recycling and other waste treatment facilities. Therefore, the PARC is looking to build on the work of HBM4EU and establish more consistent methods for occupational biomonitoring across the EU.

### *4.5.7 Antimicrobial consumption in the EU*

As detailed in Box 4.4, antimicrobial medicinal products used to treat infections with microorganisms eventually become ineffective due to the emergence of AMR. Improper use of antimicrobials in both human and veterinary medicine, as well as inadequate hygiene practices in healthcare facilities and the food industry, exacerbate this process.

In 2022, the overall sales of veterinary antimicrobials for farmed animals and in aquaculture in the EU fell by 28% compared to 2018 (Figure 4.9) with the efforts of

**Figure 4.9 Overall EU sales of antimicrobials for farmed animals and in aquaculture in the EU-27, 2018-2022**




**Notes:** A population correction unit (PCU) is used as a proxy for the size of the animal population, accounting for the population and relative weight of animals. This is used to estimate antimicrobial consumption.

**Sources:** European database of sales of veterinary antimicrobial agents (EMA, 2023) and EMA (data on total sales).

Member States and the implementation of policies under Regulation (EU) 2019/6, including stricter guidelines and national action plans. A key factor in this decline is the reduction in premix sales, which has accounted for over 60% of the annual decrease since 2018, supported by the entry into force of Regulation 2019/4. This corresponds to more than half of the 50% reduction target of the ZPAP.

Nevertheless, Member States will have to continue acting to ensure further reduction in the sales of such antimicrobials for farmed animals and in aquaculture by another 22% to hit the reduction target. The total sales of veterinary antimicrobials in tonnes follow a similar trend during the same period, meeting the target (see indicator 'Antimicrobial consumption by food-producing animals in the EU').

On the other hand, human consumption of antibacterial medication in the EU largely rebounded to pre-pandemic levels in 2022, following a drop in their intake between 2019 and 2020. In 2023, EU antibiotic consumption decreased by 1.5% compared to 2018, from 20.1 to 19.8 defined daily doses (DDD) per 1,000 inhabitants per day. In contrast, EU sales of antibacterials for human use rose from 2021 to 2022 (see indicator 'Antibiotic consumption by humans in the EU'). This renews concerns about a further increase of AMR.

# 5 Pollution impacts on ecosystems

## 5.1 Air pollution and ecosystems

**Key messages**

- Airborne pollutants significantly impact biodiversity, soil health and water quality.
- The area of habitats affected by atmospheric nitrogen deposition decreased by 13% between 2005 and 2022, indicating some progress, but the pace of change is too slow to reach the target of a 25% reduction by 2030.
- In 2022, almost a third of Europe's agricultural lands were exposed to ozone levels above the threshold value set to protect vegetation; the more ambitious long-term objective was met in only 11.2% of agricultural lands.
- Ground-level ozone reduces growth rates and crop yields and is estimated to cause at least EUR 2 billion in damage to food crops every year in Europe.

### *5.1.1 Introduction*

Airborne pollutants pose a significant threat to ecosystems across Europe, impacting biodiversity, soil health and water quality. These pollutants — which include ammonia, nitrogen oxides, particulate matter and sulphur dioxide — originate from various sources such as agricultural practices, domestic heating, industrial activities and vehicular emissions. Once released into the atmosphere, they can travel long distances, depositing harmful substances into terrestrial and aquatic environments. Furthermore, nitrogen deposition can lead to nutrient imbalances in ecosystems. These same pollutants also impact human health and well-being. Reducing their emissions will thus result in benefits for both human and ecosystem health.

These pollutants are regulated through EU actions under a range of different mechanisms, including the EU's National Emission Reduction Commitments Directive (NECD) (EU, 2016) and AAQD (EU, 2024g), as well as the EU's commitments and related legislative measures aimed at supporting the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution. Such measures are essential for protecting Europe's diverse and vulnerable ecosystems.

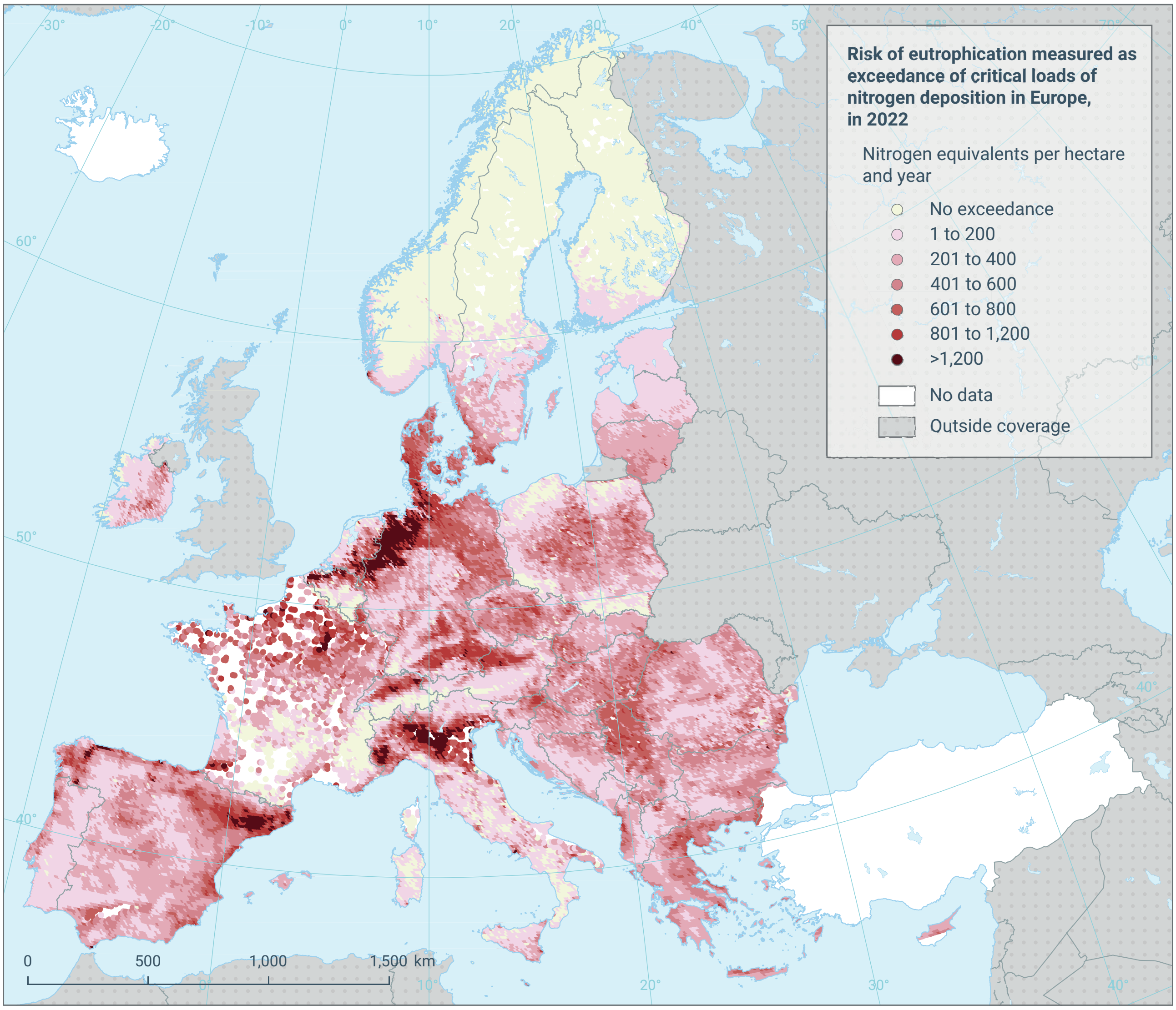
### *5.1.2 Trends in nitrogen deposition and its impact: eutrophication*

The quantitative evaluation of nitrogen deposition on land and water ecosystems is represented by the concept of critical loads. When nitrogen deposition surpasses these critical thresholds, it can result in eutrophication and the decline of biodiversity.

The primary sources of nitrogen deposition are $NH_3$ from agricultural practices and NOx from combustion processes (see indicator 'Eutrophication caused by atmospheric nitrogen deposition in Europe').

In 2005, nitrogen deposition in the EU exceeded critical eutrophication loads in 85.5% of its ecosystem area, totalling 1,235,900km[2] (EEA, 2022a). Despite a 13% reduction from 2005 to 2022 (Map 5.1), the current rate of improvement suggests that the EU will not achieve the zero pollution target of a 25% reduction in the area of ecosystems where air pollution threatens biodiversity by 2030.

**Map 5.1 Exceedance of atmospheric nitrogen deposition above critical loads for eutrophication in Europe, 2022**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

**Notes:** The map illustrates ecosystem areas at risk of eutrophication in 2022. When airborne nitrogen deposition exceeds these critical loads, an ecosystem is considered at risk of eutrophication. The map shows areas where critical loads are not exceeded (yellow shading), indicating no risk of eutrophication, and where atmospheric nitrogen deposition exceeds critical loads (different shades of red), measured in nitrogen equivalents per hectare per year.

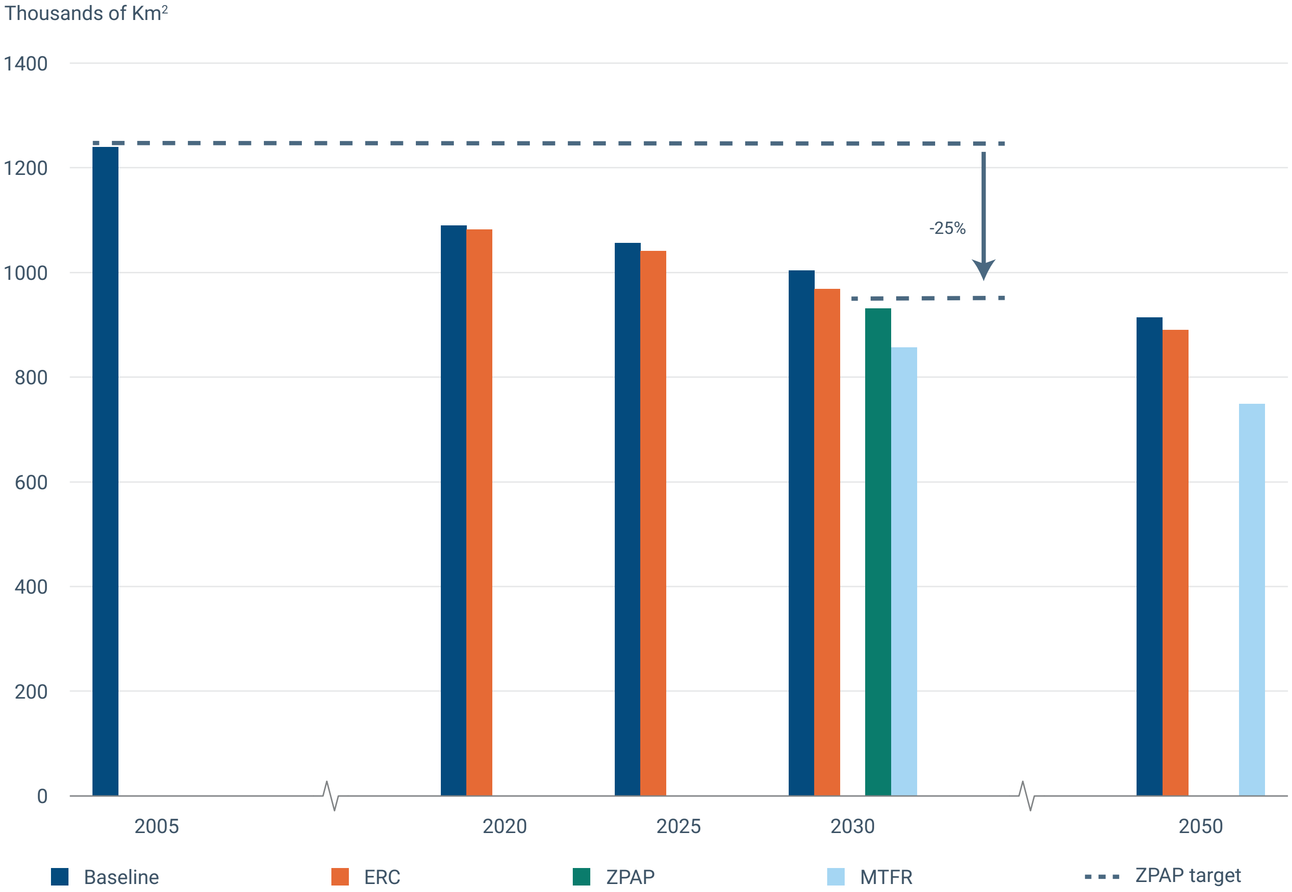
**Source:** EEA, 2024j.

### 5.1.3 Outlook

Despite a 13% reduction in nitrogen deposition from 2005 to 2022, the current rate of improvement is insufficient to meet the 25% reduction target by 2030. The 4th Clean Air Outlook's results confirm that nearly 70% of ecosystems remain affected by eutrophication in 2030. While this represents a reduction compared to 2005 by around 20%, it falls short of the targeted 25% reduction of the area of EU ecosystems with nitrogen deposition exceeding the critical loads for eutrophication (EC, 2025). This target is achieved only when assuming that all technical measures are implemented ('maximum technically feasible reduction' or MTFR scenario), leading to a reduction of 31% in 2030.

In the longer term, further improvements are achieved in all scenarios; however, even in the most optimistic case for 2050, around 50% of ecosystem area remains unprotected from eutrophication. To assess further steps necessary to achieve the ecosystem target, a dedicated scenario was developed where a cost-effective set of measures results from the GAINS ([21]) model optimisation to reach the 25% reduction. Most of the additional reduction is achieved via measures addressing emissions from cattle, followed by measures towards the mitigation of emissions from the application of mineral fertilisers, and the breeding of swine and poultry.

**Figure 5.1 Ecosystem area in the EU-27 where the critical loads for eutrophication are exceeded**




**Notes:** The marked 25% reduction of 2005 area with N deposition exceeding critical loads refers to the ZPAP target.

**Sources:** 4th Clean Air Outlook Report based on modelling by IIASA.

([21]) The greenhouse gas-air pollution interactions and synergies (GAINS) model is an integrated assessment framework developed at the International Institute for Applied Systems Analysis (IIASA).

### 5.1.4 Ammonia emissions

Ammonia ($NH_3$) emissions negatively affect biodiversity and contribute to the creation of secondary $PM_{2.5}$, which is the primary air pollutant responsible for premature deaths in the EU. Reducing $NH_3$ emissions is critical for reaching the target of reducing the ecosystem area impacted by air pollution by 25%. Ammonia is primarily released from the agricultural sector, which is responsible for 93% of the EU's $NH_3$ emissions. Emissions fell by only 16% from 2005 to 2022 (see indicator 'Ammonia emissions from agriculture and other sources').

Despite this overall reduction, a recent EEA briefing reveals that in 2022 $NH_3$ emissions have increased since 2005 in some Member States (EEA, 2024k). Reducing ammonia emissions continues to be the most significant challenge for one third of EU Member States to meeting their binding reduction commitments under the NEC Directive. This highlights the need for more effective actions at a national level targeting the agriculture sector to apply well-established agricultural practices that decrease $NH_3$ emissions.

### 5.1.5 Ozone and ozone precursors

Excessive concentrations of ground-level ozone cause damage to plants, reducing growth and leading to poorer food crop yields. The primary approach to reducing ozone levels is to control the emissions of the precursors which combine to form ozone, including NOx, methane and non-methane volatile organic compounds (NMVOC). Between 2005 and 2022, NOx emissions fell by 50% and NMVOC emissions fell by 33%, while methane emissions decreased by 20% due to falling emissions from the agriculture, energy, industry, transport and waste sectors (see indicator 'Emissions of ozone precursors-NOx, NMVOCs and methane'). Current global methane emissions from both natural and anthropogenic sources are estimated to be responsible for about 37% of the ozone background levels in Europe (EEA, 2025).

The proportion of agricultural land exposed to levels of ozone exceeding the target threshold value reached an absolute minimum of 5.5% in 2020 but went on to increase to 18% in 2021, reaching 32.5% in 2022. This amounts to a total area of 719,442km$^2$ of agricultural land being exposed to levels above the target threshold value in 2022 (see indicator 'Exposure of Europe's ecosystems to ozone'). The relatively higher values in 2022 may be related to meteorological influences on ozone formation. Crop losses in 2022 due to the impact of ozone across Europe were estimated to be around 6,700 kilotonnes of wheat, corresponding to a value of EUR 1.3 billion, and around 3,200 kilotonnes of potatoes, corresponding to a value of EUR 680 million.

### 5.1.6 Heavy metal emissions into air

The atmospheric deposition of heavy metals such as arsenic, cadmium, lead and mercury poses risks due to exposure and bioaccumulation in the food chain, with adverse effects on human health and ecosystems. These emissions originate from various sources, including industrial activities and the combustion of fossil fuel. Stringent regulations and policies have been implemented both in the EU and internationally to monitor and reduce these emissions, resulting in a significant decline in heavy metal pollution. Between 2005 and 2022 cadmium, mercury and lead emissions decreased in the EU-27 Member States by 39%, 53% and 44%, respectively (see indicator 'Heavy metal emissions in Europe'). These results align with improvements in abatement technologies and targeted legislation. Despite the regulation of many other sources, such as mercury, airborne pollution remains a critical pathway for environmental pollution, including transboundary air pollution from outside the EU. Global action, including efforts to address mercury or climate change are essential to achieving further reductions, including through the transition away from fossil fuels usage.

## 5.2 Freshwater pollution and ecosystems

**Key messages**

- Over three-quarters of groundwater bodies and only 29% of EU surface waters met good chemical status by 2021. This figure reaches 80% when persistent pollutants are excluded. The failures in surface water bodies was due primarily to a small number of persistent pollutants such as brominated flame retardants and mercury.
- Much effort has been made to reduce point source pollution in Europe's waters over recent decades. The major pathways for aquatic chemical pollution in Europe are now diffuse sources, in addition to some remaining and emerging concerns about micropollutants from municipal wastewater.
- New contaminants and chemical mixtures are impacting aquatic systems. Revisions of the Urban Wastewater Treatment and Industrial Emissions Directives and the proposal to revise the Groundwater and the Environmental Quality Standards Directive (EQSD) will help assess, prevent and curb pollution, but the benefits of these measures will take time to emerge.
- Diffuse atmospheric pollution was the most significant pressure affecting surface water bodies between 2016 and 2021. Pollution from agriculture continues to exert substantial pressure on both surface water and groundwater. Ecological farming practices and increasing consumer demand for sustainable products can help reduce pollution.
- Nutrient levels in freshwater bodies have been stable since the 2010s and achieving nutrient reduction targets by 2030 is very unlikely.

### *5.2.1 Introduction*

The ZPMO comprehensively examines the state of freshwater ecosystems, including groundwaters, lakes and rivers in Europe. The analysis — which spans decades and highlights challenges, prospects, recent developments and trends — is focused on key aspects such as the ecological and chemical status of water bodies, emerging substances, pesticides and nutrient levels.

The first ZPMA (EEA, 2022a) showed that nutrient levels decreased from the 1990s to the 2010s, but progress has since stalled, delaying the achievement of zero pollution targets. The assessment highlighted that the EU was behind in meeting the policy targets for surface waters due to legacy pollutants such as mercury. The report also revealed a lack of information on emerging pollutants like microplastics and PFAS.

Addressing these issues, amendments to the WFD, Groundwater Directive (GWD) and EQSD were proposed in October 2022. The revisions aim to regulate additional individual pollutants as well as groups of substances by setting standards. The proposed changes include an update of the WFD list of priority substances in surface water with the addition of a group of 24 PFAS, BPA and a series of pharmaceuticals including antibiotics and corresponding environmental quality standards (EQS) as well as additions to the list of pollutants regulated in groundwater (EC, 2022b). In addition, the proposed amendments to the UWWTD will further contribute to improving water quality by introducing microplastic monitoring and extending wastewater treatment to smaller agglomerations (EC, 2022a).

### *5.2.2 Quality of Europe's surface and groundwaters*

There was minimal change in the quality of Europe's waters reported across the 2016-2021 period. The introduction of more stringent standards for some existing priority substances in surface waters in 2013, made it challenging to achieve real improvements. Mercury, brominated flame retardants and polycyclic aromatic hydrocarbons (PAHs) continue to present a challenge despite them being heavily regulated or banned, particularly because they are persistent ('legacy pollution') and arise from multiple sources, including natural sources and secondary emissions from contaminated waste or sediments. In addition, they can travel long distances (from non-EU sources) in the air; this makes them still more complicated to control and eliminate from the environment.

### *5.2.3 Ecological status — surface waters*

Excess nutrients such as nitrogen and phosphorus can cause algae and plants to grow excessively, cutting out light and depleting oxygen in the water through respiration or when the plants decay. 37% of Europe's surface waters were in a good or high ecological status in 2021.

### *5.2.4 Chemical status — surface waters*

29% of Europe's surface waters were in good chemical status in the period 2016-2021, which is slightly lower than the 2009-2015 period. This is potentially due to a combination of factors including new and revised water quality standards, changes in assessment methodology and chemical pressures. A small number of ubiquitous, persistent, bioaccumulative and toxic substances (uPBTs) (see Box 5.1 and Map 5.2) — primarily brominated flame retardants and mercury — were the main cause of chemical status failure. If these pollutants were not considered, 80% of surface waters would achieve good chemical status rather than merely 29% (EEA, 2024h).

Persistent pollutants which do not readily break down into less harmful substances make it particularly challenging to achieve good status once these substances are already in the environment. Although several of the legacy priority substances first regulated in 2001 are no longer present above limit values in most of the EU's rivers and lakes and may have had their primary emissions to water phased out in the EU, they may still be subject to re-emission, for example, when sediments are disturbed by dredging operations. As pointed out in the Fitness Check (EC, 2019b), the current legislative framework is slow to adjust to the emergence of new problems. A perennial issue is that the list of regulated pollutants is limited compared with the number of substances that may, alone or in combination (see the Chemical mixtures section), pose a risk.

### 5.2.5 Chemical status — groundwater

Groundwater provides about 65% of the EU-27's drinking water and 25% of the water used for agricultural irrigation. 77% of the area of Europe's groundwater was reported to be in good chemical status for the period 2016-2021. The major pollutants of groundwater are nitrates and pesticides, most of which arise from agricultural use. Other pollutants arise following over-abstraction, where saltier water is drawn into the aquifer.

## Box 5.1

**Chemicals are causing failure of good status in surface waters under the Water Framework Directive**

Under the Water Framework Directive (WFD), failure to meet the quality standard for one substance means that the water body does not achieve the overall objective of good status. The data reported in 2016 and 2022 (by 19 Member States) show a considerable increase in the number of water bodies monitored for priority substances in 2022. The revision of the Priority Substances Directive (Environmental Quality Standards Directive) (EU, 2013) introduced some stricter quality standards and new priority substances, making it difficult to directly compare results between the two reporting cycles.

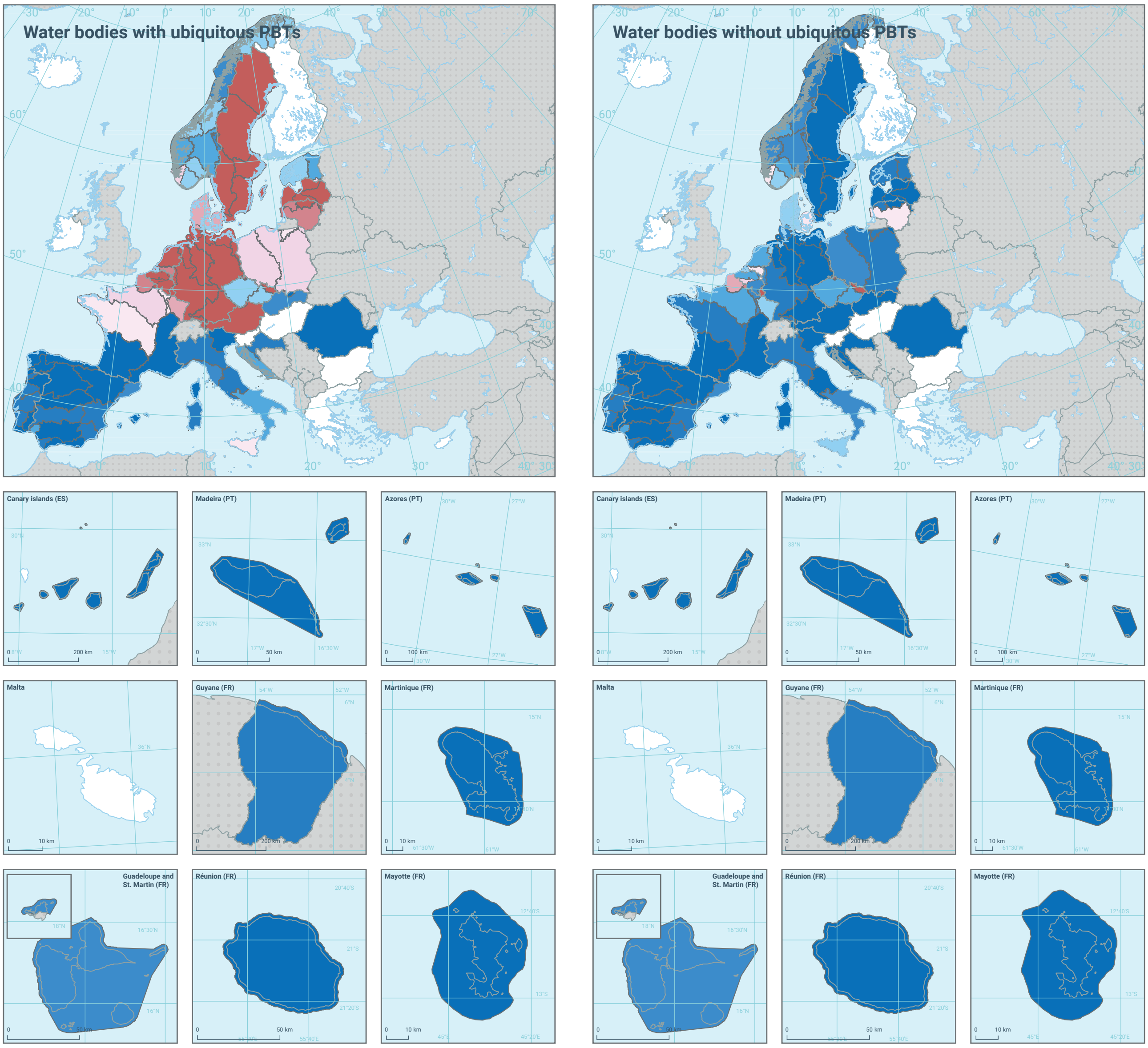
Metal residues from human activities as well as natural sources can be very toxic. 51% of surface waters failed owing to the metals classed as priority substances in 2022, an increase from 45% in 2016, which may reflect increased monitoring but could also arise from stricter standards. The failure was primarily related to mercury contamination. Excluding mercury, 2% of surface waters failed owing to cadmium, lead or nickel. Looking at all 17 metals reported in surface waters except mercury (i.e. priority substances and river basin specific pollutants), 5% of surface waters failed for at least one metal in 2022, up from 3.5% in 2016.

Excluding mercury, other uPBTs caused the failure of 27% of surface waters in 2016 but 54% in 2022, owing mainly to brominated flame retardants (following a change from monitoring in water to monitoring in biota). Focusing on the new uPBTs (heptachlors, PFOS, dioxins and hexabromocyclododecanes), 4% of surface waters failed good chemical status in 2022.

In 2022, data on the 12 priority substances added to the list in 2013 were reported, with 5% of surface waters failing at least one environmental quality standard. In contrast, for 13 of the priority substances first set in 2008, fewer than 10 surface water bodies failed in 2022. Chlorinated substances, which are very toxic in the environment, now cause rather few failures. Restrictions on pesticides and industrial chemicals such as DDT, atrazine and dichloromethane, which prevent releases to the aquatic environment, seem to have been effective in protecting surface waters from pollution by these substances.

The WFD and Priority Substances Directive require the list of priority substances and their quality standards to be regularly updated to reflect improvements in scientific knowledge relating to chemical risks. However, as substances are added and standards updated to better reflect emerging knowledge on chemical risks, it becomes even more challenging to meet good status.

**Map 5.2** **Water bodies failing to achieve good chemical status in 2021 (third RBMP) by river basin district – with uPBTs (left) and without (right)**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

**Water bodies failing to achieve good chemical status in 2021 (third RBMP) by river basin district – with ubiquitous PBTs (left) and without (right)**

Percentage

0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100

No data

Outside coverage

0 500 1,000 1,500 km

**Notes:** Maps based on WISE-SoW database, including data from 19 Member State plus Norway.

**Source:** https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive/surface-water-chemical-status

### 5.2.6 PFAS in European waters

A recent EEA briefing highlights significant concerns regarding PFOS, the most studied PFAS, which is widely present in European waters (EEA, 2024l). The exceedance of the annual average environmental quality standards (EQS) for PFOS over the period from 2018 to 2022 ranged from 51% to 60% for rivers, 11% to 35% for lakes, and 47% to 100% for transitional and coastal waters. This widespread contamination poses potential risks to human health and the environment and presents a barrier to achieving the EU's objective of good chemical status for water bodies by 2027. This emphasises the need to expand monitoring efforts to include a broader range of PFAS, enhance geographical coverage and improve analytical methods to better address these risks

### 5.2.7 Chemical mixtures

Organisms can be exposed to many different chemicals at the same time. Mixtures can lead to additive harmful effects at concentrations that may otherwise be harmless on their own. In 2020, thresholds for individual substances were exceeded at 82% of monitored sites in lakes and rivers in three case countries (Estonia, France and the Netherlands) with an additional 12% of the monitoring sites revealing the potential impacts of multiple chemicals on sensitive species (see signal 'Mixtures of chemicals in rivers and lakes in Europe'). The EC's proposal to revise the lists of pollutants under the WFD introduces a requirement for effect-based monitoring of oestrogens — a first step towards capturing mixture effects from those and, in the future, other groups of substances.

### 5.2.8 Nutrient losses

Annual input of nutrients to land by mineral fertilisers is estimated at 10 million tonnes (Mt) for nitrogen and 1Mt for phosphorus in the EU. Livestock is a major source of nutrient input to soils (i.e. 6Mt for nitrogen and 2Mt for phosphorus). Annual losses to the environment from transport, agriculture, industrial, domestic and other human activities amount to around 8Mt of nitrogen emissions to air and about 5Mt of nitrogen and 0.3Mt of phosphorus losses to water (Grizzetti et al., 2023). A significant share of this amount eventually reaches the sea. Box 5.2 explains the impacts of nutrient pollution on the environment and human health, and outlines EU policies and strategies to reduce nutrient losses.

The EU made good progress in curbing nutrient losses during the 1990s. Since 2000, nutrient losses from urban areas and industry have fallen due to consistent progress in expanding wastewater treatment coverage. However, there has been a stagnation in decreasing trends in the last decade. The average nitrate and phosphate concentrations in rivers and total phosphorus concentration in lakes and rivers levelled off after the 2010s as illustrated in Figure 5.2 (see indicator 'Nutrients in freshwater in Europe'). The average nitrate concentration in EU groundwaters has not changed significantly since 1997 (Figure 5.2a). In European rivers, biochemical oxygen demand levels have halved between 1992 and 2022 but remained steady since 2010. Ammonium concentrations decreased to 20% of the 1992 level in 2014 but levelled off since 2014 (see indicator 'Oxygen consuming substances in European rivers').

## Box 5.2

**Nutrients**

Nutrients such as nitrogen and phosphorus are fundamental elements for organisms and plant growth. They are naturally present in the environment in different chemical forms. In Europe, intensive agriculture, wastewater discharges and emissions from transport and industrial activities have increased nutrient losses to air, soil and water. High levels of nitrates in drinking waters and nitrogen oxides in air are dangerous for human health. Excessive levels of nutrients in rivers, lakes and marine waters can lead to eutrophication causing algae overgrow and water oxygen depletion, with detrimental impacts on aquatic ecosystems, water quality, and activities like tourism and fishing. Ammonia emissions from intense livestock facilities and mineral and manure applications in agriculture contribute to air pollution and acid deposition on soils and water bodies. Nitrous oxide, produced in denitrification processes in soils and waters, acts as a strong green house gas (GHG), contributing to climate change.

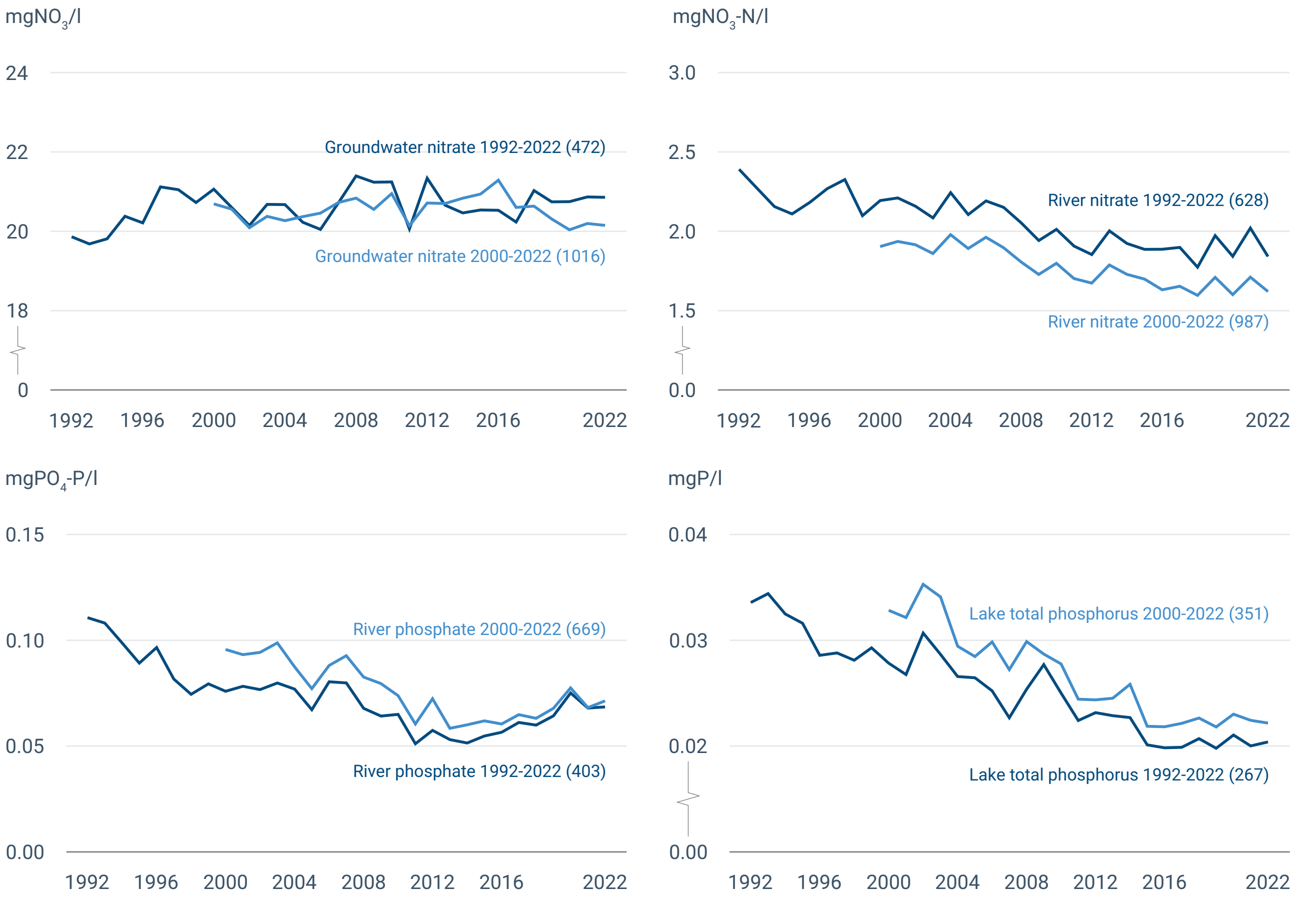
EU policies such as the Nitrates Directive, UWWTD, IED, WFD and Marine Strategy Framework Directive (MFSD) aim to address nutrient pollution and the reduction of nutrient emissions across various sectors and compartments (EU, 2016). The zero pollution target to reduce nutrient losses by 50% by 2030 is aligned with other targets and international commitments such as the Kunming-Montreal Global Biodiversity Framework Target 7 (UNEP, 2022).

Looking ahead, various actions in the European Green Deal (EGD) aim to reduce nutrient losses to the environment. These include the revised UWWTD to reduce point sources of pollution to water; the Fit For 55 package to lower nitrogen emissions to air and atmospheric deposition; and the new Common Agricultural Policy's strategic plans to promote sustainable agriculture. Despite these efforts, intensive agriculture and livestock as well as the international import of animal feeds will continue to contribute to nutrient losses in Europe and outside the EU. To achieve the zero pollution targets for nutrient losses, there needs to be a reduction of about 50% in the annual new input of nutrients to remain within safe planetary boundaries. This could be achieved by more sustainable agricultural practices, increasing nutrient recycling, scaling up nature-based solutions and by dietary changes with less meat consumption, which would also align with health recommendations.

The first Zero pollution outlook report (JRC, 2022) concluded that coastal marine regions show bigger improvements in eutrophication status than open waters. To prevent adverse impacts on marine ecosystems, such as harmful algal blooms, it is essential to develop smart nutrient reduction strategies that consider the relative molar ratio of nitrogen and phosphorus.

Considering the complexity of nutrient cycles and the involvement of numerous sectors and environmental compartments involved, development on an Integrated Nutrient Management would be instrumental for coordinating policy actions and maximising benefits (Grizzetti et al., 2023).

**Figure 5.2 Nitrates in groundwater and rivers, and phosphorus in lakes and rivers**




**Note:** Number of monitoring stations are given in brackets.

**Sources:** EEA, 2024m.

### *5.2.9 Outlook*

The outlook for the future indicates that, under current measures, the ZPAP's nutrient reduction target will not be achieved by 2030 (Grizzetti et al., 2023). Current EU policy should result in a decrease in nitrogen oxide (NOx) emissions to the air and in nutrient emissions to water from urban wastewater treatment plants. However, it is anticipated that nitrogen losses from agricultural sources (mainly ammonia emissions to the air and nitrate losses to water) will not decrease significantly unless other measures are taken into consideration, such as those proposed under the F2F and BDS or changes in agricultural practices and dietary patterns (Billen et al., 2024). Measures to be introduced under legislation such as the Nature Restoration Regulation and the revised IED are also expected to beneficially reduce nitrogen losses from agriculture.

The shift to agro-ecological practices involving less mineral fertiliser input and more manure recycling would reduce the environmental impacts of nutrient pollution in the EU and elsewhere. In addition, moving towards a more healthy and equitable human diet with less (-50%) meat consumption would have a positive effect on the reduction of nutrient fluxes, including nitrogen emissions to air (ammonia and nitrous oxide) and nitrate leaching into water. This shows that behavioural changes can significantly support zero pollution targets. Moreover, both practices would also improve food security by making the EU more self-sufficient in terms of mineral fertilisers, food and livestock feed.

A recent study on EU policy and climate projections for 2050 indicates that, under the current policy, nutrient reduction targets will not be achieved — despite reductions in nitrogen emissions to the air via the Fit for 55 measures and the revised Urban Waste Water Treatment Directive — as agriculture will remain an important source of nutrient losses to the air and water in several European regions (Grizzetti et al., 2024).

#### *5.2.10 Pesticide pollution*

The use of pesticides in agricultural, residential and industrial settings can contaminate freshwater bodies through various pathways including runoff, leaching (through soil), spray drift and illegal disposal or release into water bodies.

The harmonised overall indicator for pesticide use and risk shows a declining trend (see Figure 4.7 under Section 4.5). Still, between 2013 and 2022, one or more pesticides were detected above their effect threshold at 10% to 25% of surface water monitoring sites, with no significant decline in recent years. Exceedances were often caused by the imidacloprid, cypermethrin and the herbicide metolachlor.

For groundwater, exceedances by one or more pesticides were detected at between 4% and 13% of groundwater monitoring sites, mainly related to atrazine and its metabolites, as well as glysophate and bentazone. Despite restrictions on certain substances such as atrazine (since 2007), some pesticides continue to be found in groundwater because they are persistent. While individual pesticide residues may have low toxicity, the overall environmental risk of chemical mixtures may be significant, even if usually driven by a few key substances.

### 5.3 Marine pollution and ecosystems

**Key messages**

- The EU is still not on track to meet the MSFD's 'good environmental status' targets. Only small improvements have been made in chemical pollution and eutrophication.
- Most pollution in the seas originates from land-based sources. The EU should focus on reducing chemical, nutrient and plastic releases at their sources. Additionally, sea-based activities such as shipping and aquaculture are increasingly impacting the marine environment and require targeted action.
- Beach litter decreased by 29% between 2015 and 2021 — a significant step towards the 2030 target of reducing sea litter by 50%.
- Future projections and new measures to curb plastic pollution suggest we can expect further reductions in micro and macroplastic emissions

- Between 2016-2022, a 7-9% increase was estimated in microplastic releases. However, recent EU legal measures on microplastic releases are expected to help reduce this form of pollution.
- Legacy hazardous substances and heavy metals that are persistent will continue to impact marine ecosystems and eutrophication is likely to remain a significant pressure.
- Underwater radiated noise is expected to continue increasing in a business as usual scenario. However, shipping source noise can be reduced by up to 70% by 2050 if EU and international policy measures are integrated with technological innovations.

### *5.3.1 Introduction*

Europe's marine ecosystems continue to be affected by multiple pollution sources from land and sea-based human activities such as agriculture, aquaculture, fishing, industry and shipping.

The seas act as a repository for pollution originating from both land and marine sources. While measures are being taken to reduce pollution at source, the positive impacts of some zero pollution measures (e.g. on persistent chemicals) will likely only be observed years later in the sea. An evaluation of the MSFD has been initiated, which provides an opportunity to curb sea pollution (EC, 2021c). Additionally, the EC announced in June 2023 a package of five legislative proposals to modernise EU rules on maritime safety and prevent water pollution from ships.

The previous ZPMA in 2022 showed nutrient pollution, primarily from agriculture, was a major driver of eutrophication (EEA, 2022a). Hazardous chemicals such as persistent organic pollutants and heavy metals from industrial discharges and agricultural runoff continued to pose severe risks to marine life. Despite efforts to reduce these pollutants, legacy pollution remained a persistent challenge. According to the assessment, marine litter was a widespread problem across Europe's seas, harming marine organisms through ingestion and entanglement. Additionally, URN was increasing.

The 2025 ZPMO provides an overview of the state of marine ecosystems in Europe, with a focus on prevalent pollution issues. Addressing key concerns such as eutrophication, chemical pollution, marine litter and underwater noise pollution, the analysis explores the impact of legacy substances and the effectiveness of pollution control measures outlined in the ZPAP and the MSFD. The assessment highlights regional variations and ongoing challenges.

### *5.3.2 Contamination of Europe's seas*

Europe's seas showed varying statuses for chemical pollution. The North East Atlantic (NEA) Ocean showed improvement. Despite reductions in legacy pollutants, the Baltic Sea remained largely unfavourable with most areas rated as bad or poor status and the Mediterranean Sea displayed a mixed status with some regions achieving good status while others lagged behind.

- NEA Ocean: The 2023 Oslo and Paris Conventions (OSPAR) showed significant reductions in legacy pollutants due to OSPAR and EU measures, but the pace of improvement has slowed (OSPAR, 2023a). Environmental concentrations of most metals and substances remained above background values. Mercury and PCB 118 (a dioxin-like polychlorinated biphenyl — a synthetic organic chemical) are still above levels that harm the marine environment. While cadmium and lead exceed background levels, their overall status was considered good. The Southern North Sea had higher concentrations of persistent organic pollutants, with organotins, from plant protection and biofouling prevention, being most concentrated near shipping lanes and ports.

- Baltic Sea: Hazardous substances in the Baltic Sea showed slight improvement, but the overall status remained unfavourable between 2016 and 2021 (HELCOM, 2023). About 80% of assessed marine areas were rated as bad or poor status, six open sea sub-basins improved since the previous assessment, though not reaching good status. Individual monitoring stations indicated slight improvements.

- Mediterranean: The 2023 Mediterranean Action Plan (MAP) assessment indicated the marine environment's status varies in the Central Mediterranean sub-region (UNEP-MAP, 2023). The Alboran Sea and North Adriatic are in poor status for acute pollution events, while the other part of the Western Mediterranean is in moderate status. For total mercury and organic pollutants (PAHs and PCBs) in the Adriatic Sub-region, 80% were in high/good status and 20% were in moderate status. In the Central Western Mediterranean, 6 out of 7 assessment units were in high/good status and one was in moderate status.

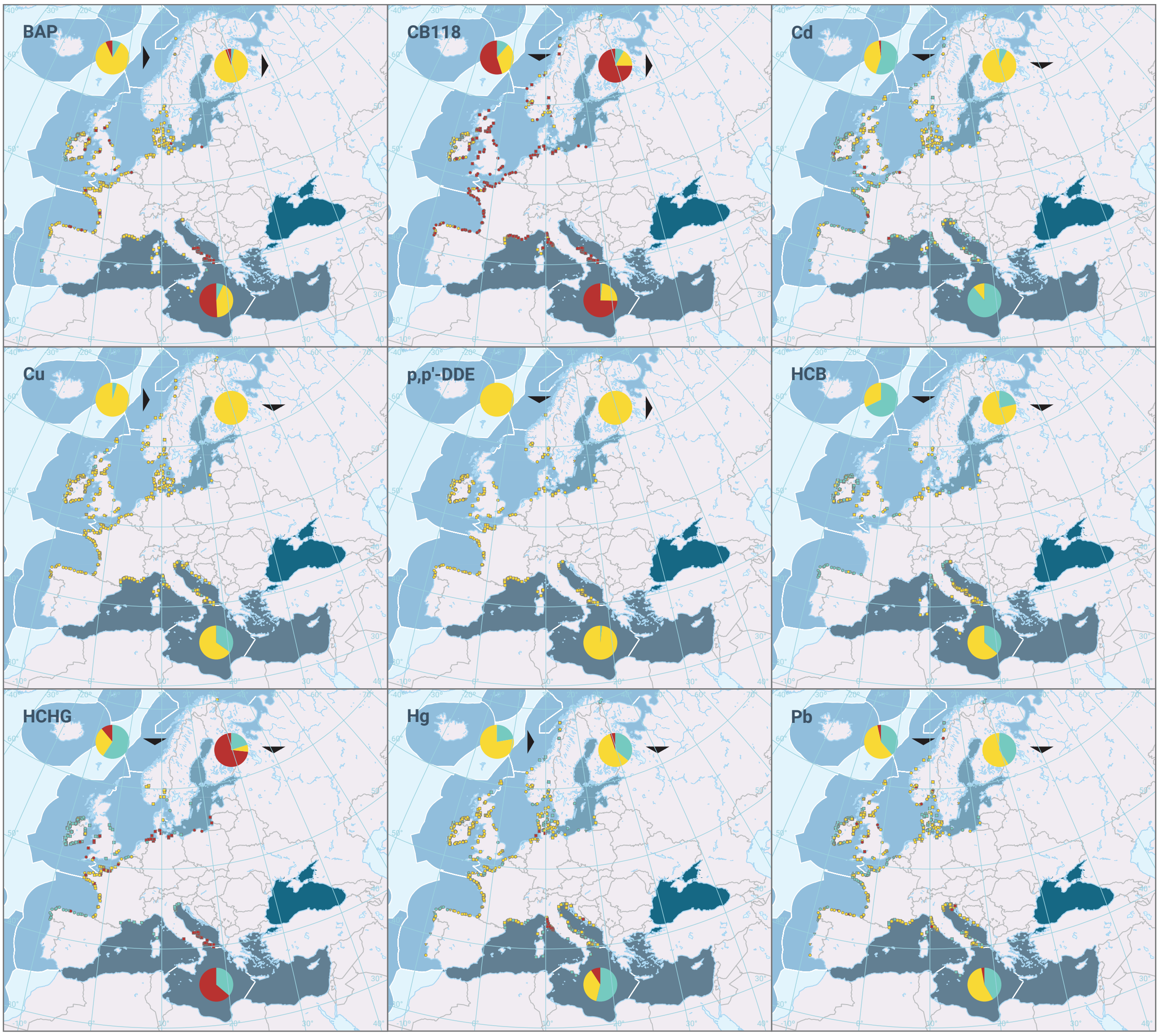
### *5.3.3 Contaminants in marine organisms*

Nine hazardous substances (legacy pollutants, nearly all of which have been banned) were assessed in mussels and oysters in the period 2010-2021. Exceedances of safe limit values were identified for all monitored substances — especially for benzo(a)pyrene, DDE (dichlorodiphenyltrichloroethane; breakdown product of dichlorodiphenyltrichloroethane (DDT)) and PCBs. However, the few available time trends showed that there were more decreasing trends than increasing ones, except for mercury.

Europe`s seas are contaminated by both legacy and currently used substances. Increasing concerns have been raised for per-and polyfluorinated substances (PFAS originating from various sources such as consumer products (including clothing, cosmetics and food packaging) and industrial processes. They are regularly found in marine organisms. Long-chain PFAS, including PFOS and PFOA pose significant risks to marine organisms and human health. PFOS concentrations in marine organisms were found at levels up to 100 times greater than the EU Environmental Quality Standard. Additionally, many other PFAS that have not been monitored may also pose unknown risks. The proposed revision of the WFD — which includes 24 PFAS in the list of priority substances in surface waters and in the list of groundwater pollutants — aims to improve our understanding of and limit human and environmental exposure to these hazardous chemicals.

Future projections of PFAS and PFOS in the Black Sea indicate that, even with a 50% reduction in their inputs through rivers, concentrations at sea will reduce by a substantially lesser amount. To address the risk posed by PFAS and PFOS in the marine environment it will be necessary to minimise emissions of these substances from key sources such as urban wastewater treatment plants.

**Map 5.3** **Hazardous substances in marine organisms in Europe's seas**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

**Hazardous substances in marine organisms in Europe's seas**

Concentrations
- High
- Moderate
- Low

Concentration trend
- △ Increase
- ▽ Decrease
- ○ No trend
- □ Trend unkown

Seas
- Baltic Sea
- Black Sea
- Mediterranean Sea
- North-East Atlantic Ocean

Regional concentration trend
- Improvement (decreasing concentrations)
- No change

Definitions of the substances

BAP=Benzo[a]pyrene CB118=(the dioxin-like CB118) one particular polychlorinated biphenyl (PCB) Cd=Cadmium
Cu=Copper p,p'-DDE = breakdown product of DDT HCB=Hexachlorobenzene
HCHG=Gamma hexachlorocyclohexane (γ-HCH) Hg=Mercury Pb=Lead

0 500 1,000 1,500 km

*This map serves as a working mean only and shall not be considered as an official or legally-binding map representing marine borders in accordance with international laws. This map shall be used without prejudice to the agreements that will be concluded between Member States or between Member States and non-EU Countries in respect of their marine borders.*

**Sources:** EEA, 2024l.

### 5.3.4 Eutrophication of Europe's seas

Between 1980 and 2021, nutrient levels have significantly decreased in the Baltic and Greater North Seas; however, eutrophication remains a widespread problem across Europe's seas. Phosphorus concentrations continue to rise in some regional seas, such as the Baltic Sea, requiring further action to address the issue. Since the late 20th century, sea temperatures across Europe have increased due to climate change, which has also led to more frequent algal blooms and a heightened eutrophication risk (EEA, 2023h).

The EEA's Nutrients in Europe's transitional, coastal and marine waters indicator (see indicator 'Nutrients in Europe's transitional, coastal and marine waters') shows an overall decreasing trend in 14% of the nitrogen time series, an increase in 2%, while 84% shows no significant trend. 11% of the phosphorus time series shows a decrease, with 7% having an increase and 82% showing no significant changes between 2017-2021 (Figure 5.3).

Analysis of chlorophyll in Europe's transitional, coastal and marine waters (see indicator 'Chlorophyll in transitional, coastal and marine waters in Europe') indicates that 95% of the monitoring points do not show significant changes in nutrient levels and chlorophyll. In summary, eutrophication is slightly decreasing in certain areas but remains largely unchanged in Europe's seas.

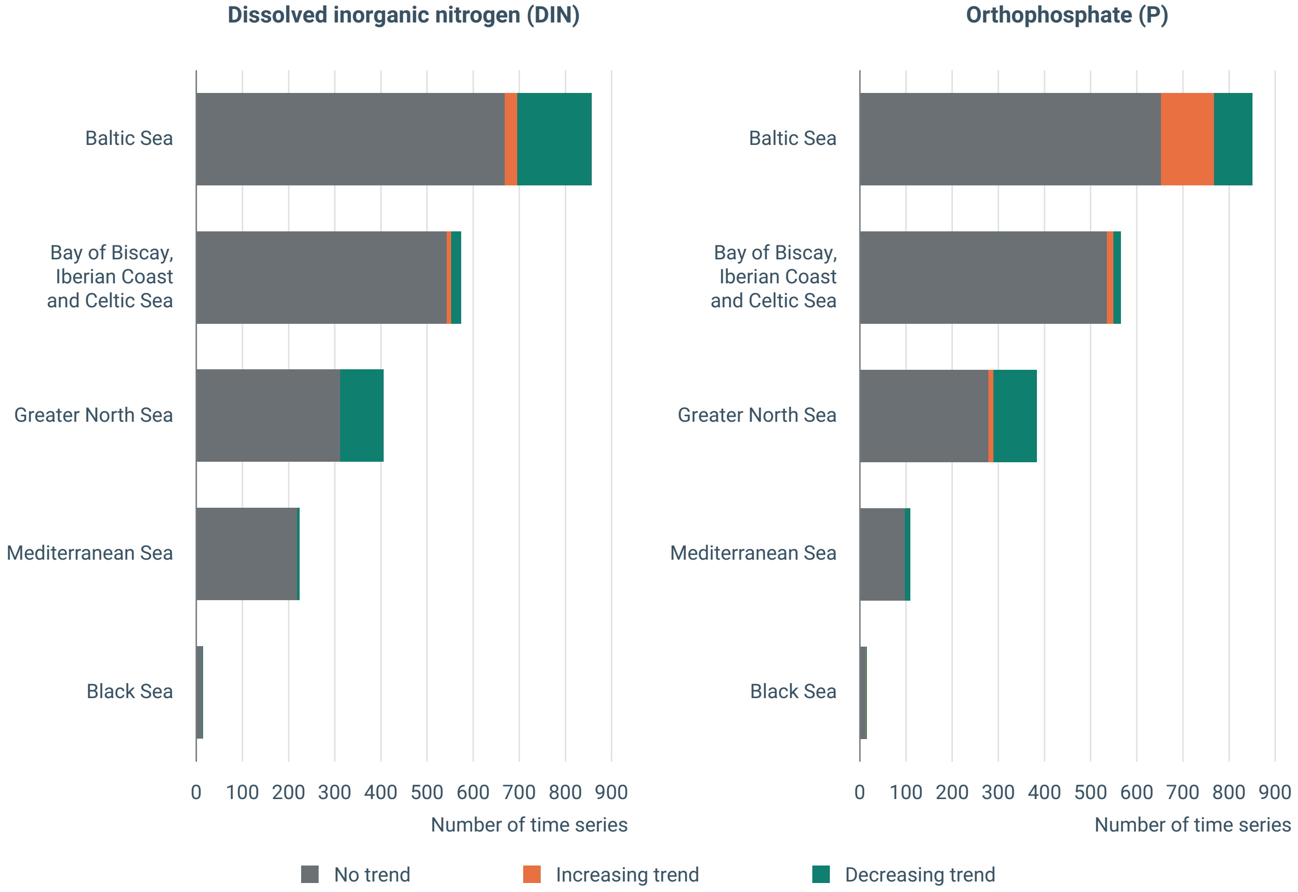
- Regional assessments indicate that the Baltic Sea continued to be impacted by eutrophication between 2016 and 2021. Only 12 out of the 252 marine assessment units included in the Baltic Marine Environment Protection Commission assessment achieved good status (HELCOM, 2023). Additionally, 93.8% of the Baltic Sea's surface area, spanning from the Kattegat to the inner bays, was affected by eutrophication.

- Approximately 6% of the NEA Ocean OSPAR maritime area is eutrophic (OSPAR, 2023b). Eutrophication problems persist along the continental coasts from France to Denmark/Sweden. Mainly river plumes and coastal areas were affected by eutrophication, indicating that the major source remains riverine nutrient inputs. The region has seen significant growth in aquaculture, leading to notable increases in waterborne nutrient inputs. Despite improvements in industrial discharges and wastewater treatment, these have been nearly offset by the nutrient increases from marine aquaculture.

- The MAP assessment for 2018-2021 indicates that eutrophication indicators were generally in good condition, except in areas with high anthropogenic pressures (UNEP-MAP, 2023). In the Aegean Sea, only two sub-marine units ([22]) demonstrated bad status due to urbanisation, industrial activities and agricultural discharges. Assessment zones demonstrated good status for chlorophyll in the Levantine Sea. All sub-marine units in the Adriatic Sea met good status. In the Central Mediterranean, 7 out of 36 sub-marine units were in good status. In the Western Mediterranean waters of Spain, 8 out of 70 sub-marine units were identified as having a bad status.

([22]) In the context of the MAP assessments, 'sub-marine units' and 'marine units' refer to specific geographic and ecological divisions used to manage and assess the marine and coastal environment of the Mediterranean region.

**Figure 5.3** **Time series showing increasing, decreasing or no trends in dissolved inorganic nitrogen and orthophosphate concentrations for each regional sea during the period 2017-2021**




**Source:** EEA, 2024m.

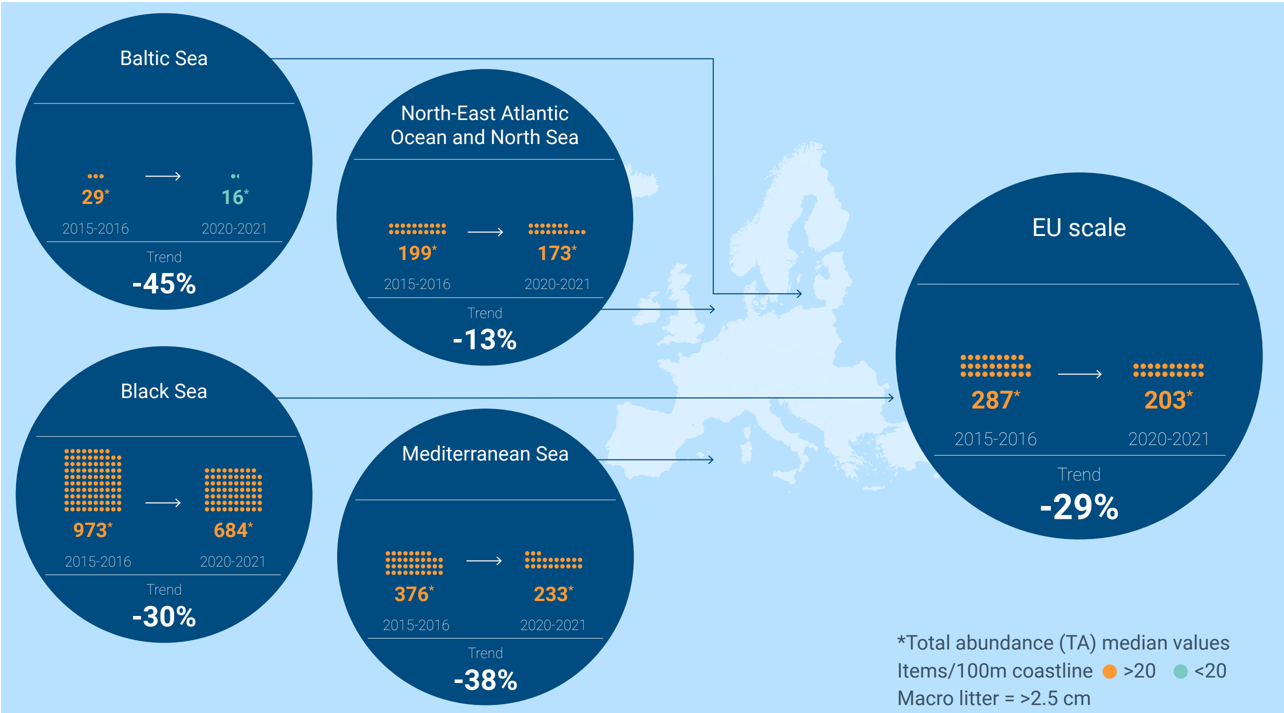
### *5.3.5 Outlook*

As indicated in the first Zero pollution outlook 2022, future scenarios of eutrophication at EU marine regions show larger improvements in coastal areas than in the open sea. Still, overall reductions are not large enough to fulfil the zero pollution objectives. Furthermore, modelling forecasts call for smart nutrient input reduction strategies to avoid drastically altering the relative nitrogen to phosphorus ratio in marine ecosystems. Otherwise, undesirable effects such harmful algae blooms could result.

### *5.3.6 Plastic pollution in Europe's seas*

Harmonised beach litter data reported under the MSFD between 2015 and 2021 indicate that concentrations of plastic litter declined by 29% along EU coastlines ([23]) (JRC, 2024). Single-use plastics have decreased by 40%, fishery-related items saw a 20% reduction and plastic bags dropped by 20%. The data analysis suggests that the zero pollution target of a 50% reduction in plastic litter at sea could be achievable by 2030 if the current trend continued. Nevertheless, the concurrent upward trend in European plastic production highlights the necessity for advancements in managing waste and preventing leakages to maintain this positive trend.

**Figure 5.4 European coastline macro litter trends, 2015-2021**




**Note:** The total abundance of marine macro litter, defined as the sum of items of all categories of macro litter on EU coastlines, is represented by the dots.

**Sources:** JRC, 2024.

According to the assessments performed by the regional sea conventions, marine litter levels in Europe's regional seas exhibited notable differences.

- In the OSPAR region, seafloor litter was widespread and despite a reduction in beach litter and floating litter in the North Sea from 2009 to 2018, the amount of litter remained high (OSPAR, 2023c). There was a high incidence of plastic ingestion by animals, such as seabirds and sea turtles, with 51% of beached North Sea fulmars having more than 0.1g of plastics in their stomachs, exceeding OSPAR safe threshold values. Additionally, marine litter causes entanglement, affecting over 900 species and leading to physical harm and death, thereby disrupting marine ecosystems in the OSPAR region.

([23]) ZPMA 2022 and ZPMO 2024 assessments use 'beach litter' data as a proxy indicator for the amount of litter in the sea.

- In the Baltic Sea, between 2016 and 2021, 11 out of 16 assessed sub-basins surpassed the threshold value for beach litter (20 items per 100m) and seafloor litter showed stable amounts with an increase in fisheries-related litter weight (HELCOM, 2023).
- In the Mediterranean Sea, according to the MAP assessment criteria, only 16% of the monitored beaches achieved good status for macro litter, 99% of monitored stations failed to achieve good status for floating microplastics and 88% of seafloor stations were not in good status between 2018-2021 (UNEP-MAP, 2023).

### *5.3.7 Outlook*

Future projections of macroplastic emissions and their distribution through EU marine regions show that, under a business-as-usual scenario considering full implementation of coming policies and more efficient waste management, an overall reduction of 42% could be expected by 2030. Regional variations are likely, with models indicating a range of reductions from 38% in the south-eastern Atlantic basin to 48% in the Baltic Sea basin. With expected policies in place, the target reduction of 50% will be only achieved in 34% of the EU marine regions' coasts (or in 52% of the European MS beaches). Henceforth, more ambitious measures are to be taken including international collaboration and engagement (particularly for shared basins).

### *5.3.8 Microplastic releases to the environment*

Microplastics are increasingly recognised as a significant emerging pollutant. They are harmful to ecosystems but their effects on human health are still unclear (for details see Box 4.5).

In the absence of a formal indicator of microplastic emissions, the EEA developed a proxy indicator based on datasets of activities and sales related to microplastic releases. Using these approximations, a slight increase was estimated in the release of microplastics from pre-production pellets, paints, tires and textiles of approximately 7-9% in 2022 compared to 2016. Specifically, tyre abrasion emissions increased by 12.3%, plastic pellet emissions rose by 7% and paint emissions increased by 5% (See indicator 'Microplastic releases to the environment').

### *5.3.9 Outlook*

Recent EU legal measures on microplastics releases are expected to help the achievement of the zero pollution target (a 30% decrease in microplastic releases by 2030); however, they will not be sufficient, as there will not be enough time to observe their full impact. An impact assessment (EC, 2023e) for the proposed Regulation on preventing pre-production pellet loss concluded that a 6% reduction of the total amount of microplastic releases can be achieved through this measure, once fully implemented. The microplastic restriction under REACH could contribute another 1% until 2030 (ECHA, 2020). These estimates are subject to substantial uncertainties and do not consider developments that only indirectly affect microplastic emissions, such as the ban on certain single-use plastic products (EU, 2019) and a reduction in plastic litter through a revision of the legal provisions on Packaging and Packaging Waste. Overall, considering the estimated slight increase during the period 2016-2022 (4-5%) and the projected cumulative reduction of about 7%, it is likely that there is rather a steadiness than a reduction of microplastics release until 2030 compared to the baseline year. According to these estimates, which have a high level of uncertainty, the EU is off track to achieving a 30% reduction by 2030.

### 5.3.10 Underwater noise pollution

Noise pollution from human activities — particularly maritime traffic, offshore industries and specific military activities — poses a significant threat to marine life. This noise can lead to behavioural and physiological changes in animals, habitat loss and even extinction risk (EMTER, 2021), Regional assessments show that:

- Impulsive noise in the OSPAR region, particularly in the Greater North Sea, increased from 2015 to 2019 (OSPAR, 2023d);
- In the Baltic Sea, the status of underwater noise was generally good between 2016 and 2021 but high continuous noise levels were detected, leading to behavioural disturbances in fish or marine mammals. In 9 out of 17 areas assessed areas, noise made it difficult for fish to hear natural sounds (HELCOM, 2023);
- In the Mediterranean Sea, the status of underwater noise was likely to be acceptable according to the good status threshold defined by MAP, which stipulates that no more than 10% of a marine habitat should be impacted by impulsive noise over a year for selected cetaceans (UNEP-MAP, 2023).

### 5.3.11 Shipping-related noise

Shipping is known to be a primary contributor to anthropogenic, continuous underwater radiated noise (URN) in the oceans (EMSA, 2021; Tasker, 2016). The highest sound pressure levels from shipping induced URN (120-130dB) are observed in regions such as the Adriatic Sea, Dardanelles, English Channel, Strait of Gibraltar, and parts of the Baltic Sea. In contrast, the lowest sound pressure levels are found in the northwest of the Northeast Atlantic (around the Denmark Strait and Irminger Sea), southern Mediterranean, and eastern Black Sea. However, limited Automatic Identification System coverage in these areas may affect the accuracy of these results (EMSA, 2024). Seasonal temperature variations influence sound propagation, with stronger propagation in winter and spring leading to higher URN levels, and weaker propagation in summer resulting in lower URN levels. This seasonal effect is less pronounced in shallow areas like the Baltic Sea and the North Sea. The trends are further explored in the accompanying zero pollution indicator on continuous underwater radiated noise (see indicator 'Underwater noise pollution in Europe's seas').

### 5.3.12 Outlook

The ZPAP aims to reduce URN to levels that do not adversely affect the marine environment. However, short- and medium-term progress in reducing shipping-related underwater noise remains relatively slow, due to the gradual replacement of noisy ships and growing global traffic.

To address this, the European Maritime Safety Agency's (EMSA) NAVISON project has developed forecast models to evaluate the impact of various mitigation strategies for reducing URN (EMSA, 2024). Foresight analysis indicates that the implementation of technical and operational URN and GHG mitigation measures may lead to a substantial reduction in URN for all ship types and in all regions by 2050. In specific cases, this reduction could be as much as 70% compared to the business-as-usual scenario. Efforts at the EU and international levels, alongside the adoption of new technologies and operational practices, will be crucial to achieving this reduction.

## Box 5.3

**Reducing light and noise pollution — Addressing the ecological impacts**

Anthropogenic light not only exacerbates climate change through energy consumption but also disrupts species and ecosystems globally (Jägerbrand and Spoelstra, 2023). According to the first ZPMA, artificial light at night (ALAN) is an emerging pressure, with its intensity and extent steadily increasing. This is particularly the case in Europe, with an estimated reduction of 5% in 'truly dark spaces' between 2014-2015 and 2020-2021. The ecological impact of ALAN is extensive and multifaceted. As anthropogenic light becomes more widespread, it is increasingly disrupting ecosystems, leading to significant disturbances across a wide range of species. For instance, the attraction of nocturnal insects to light sources leads to their death from exhaustion or predation, thereby affecting food webs and contributing to biodiversity loss (Hölker et al., 2023). A summary of potential impacts can be found in Jägerbrand and Spoelstra, 2023.

Noise pollution, like light pollution, is a growing environmental concern as human activities continue to expand into natural habitats. It is primarily caused by transportation systems (air, maritime and terrestrial), industrial activities, urbanisation and recreational activities, all of which generate excessive sound levels that can interfere with natural acoustic environments. It affects not only humans but also significantly impacts biodiversity, influencing various behavioural, physiological, communication and sensory perception processes.

The impact of transportation noise on terrestrial biodiversity is an evolving field of study, with most research focused on birds, followed by mammals, amphibians, insects, reptiles and arachnids. It can disrupt communication, navigation and predator-prey detection, altering foraging, mating and territorial behaviours. This is explained further in the Zero pollution signal on the impacts of environmental noise on biodiversity (see signal 'Impacts of environmental noise on biodiversity').

Specific legislation targeting light pollution remains limited. To mitigate the ecological impact of ALAN, key strategies include adopting energy-efficient and wildlife-friendly lighting technologies which minimise blue light emissions and reduce sky brightness (Falchi et al., 2016). Public awareness campaigns aimed at local authorities, industries and citizens are crucial for promoting better lighting practices, such as installing motion sensors and limiting unnecessary lighting. Urban planning can further support these efforts by establishing rules that limit light spillover and ensure artificial light is used only where necessary, reducing the environmental impact of cities (Taraves et al., 2021).

In terms of noise pollution, the EU's END primarily addresses the health impacts of environmental noise on humans but does not directly link noise pollution to wildlife. On the other hand, the MSFD sets limits to protect marine biodiversity from harmful underwater noise caused by activities like shipping and offshore construction, which negatively impact marine life, especially endangered species, through stress and behavioural changes. Other instruments, such as the Habitats and Birds Directives, the Biodiversity Strategy for 2030 and the Natura 2000 network indirectly support biodiversity conservation, including noise-sensitive species, however these address noise as a more general threat rather than proposing specific actions. The Green City Accord and the EU Green Infrastructure Strategy also contribute by promoting the reduction of noise and the creation of green spaces, which are critical for biodiversity in urban areas (see signal 'Impacts of environmental noise on biodiversity').

In 2024, two new projects funded under Horizon 2020 and Horizon Europe were launched to address the impacts of light and noise pollution on biodiversity. The AquaPLAN project aims to assess the combined effects of these pollutants on aquatic ecosystems in European waters and develop interdisciplinary strategies for their management. Meanwhile, the PLAN-B project focuses on terrestrial ecosystems, working to understand and mitigate the negative impacts of light and noise pollution on biodiversity and ecosystem services. Both projects support nature restoration and contribute to achieving the objectives of the EU Biodiversity Strategy.

Together, these actions form part of a broader effort to mitigate the environmental impacts of both light and noise pollution across Europe.

## 5.4 Soil pollution and ecosystems

**Key messages**

- Local and proximity pollution (e.g. from industry, waste) as well as diffuse agricultural inputs continue to cause high concentrations of metals and organic pollutants and introduce potential AMR drivers and excess nutrients.
- Modelling indicates that long-term sewage sludge application, without adequate control of sludge quality, could significantly contaminate agricultural soils.
- Pesticide residues were found in 75% of EU soils monitored in the 2018 LUCAS survey. The presence of pesticide residues in soils, both from historic as well as current inputs, poses a risk to non-targeted soil organisms. Among the risk drivers, several substances such as chlorpyrifos, epoxiconazole and imidacloprid are no longer approved.
- The binding EU regulation on mercury is expected to decrease its impact in the future. This is attributed to the implementation of control technologies, reduced mining and different metallurgical processes.
- The proposed EU Soil Monitoring and Resilience Directive pursues a risk-based approach to soil health, with a focus on soil pollution. It urges Member States to establish critical limits and to promote specific remediation techniques to restore soils.

### *5.4.1 Introduction*

Healthy soils are essential for strengthening resilience against all pressures including climate change and flood risk, intensive application of agrochemicals and the impact of urban sprawl. The unsustainable use of soils causes the loss of fertility, affecting the growth and health of plants and reducing agricultural productivity, it is therefore essential for the agriculture and food system. Pollution can also disrupt soil community composition, affecting biodiversity. Pollutants can migrate to aquatic ecosystems via surface runoff or groundwater transport and accumulate in the food chain.

The assessment of soil pollution in the EU is mostly based on the 2018 LUCAS survey (JRC-ESDAC, 2022), whereas various Member States have national monitoring procedures and legislations in place. At the EU level, various metals and metalloids as well as pesticide residues have been investigated since 2009 (Vieira et al., 2024). The EU Soil Observatory — through the newly-introduced Soil Health Dashboard (Panagos et al., 2024) — has provided insights into regions with higher soil pollution risk by mapping, for the first time, areas with high concentrations of heavy metals such as copper, mercury, zinc, arsenic and cadmium.

The EU's proposed SML aims to create a harmonised soil information system across Member States, addressing soil contamination and promoting soil health (EC, 2023g). It would establish soil chemical and biological descriptors to be representatively monitored. To enable healthy soils in the EU, Member States will be asked to establish sustainable soil management principles.

### *5.4.2 Heavy metals in EU soils*

According to the LUCAS topsoil survey, cadmium concentrations exceed 1mg/kg in 5.5% of samples (Ballabio et al., 2024). Various natural factors such as clay content, erosion, organic matter content and pH impact cadmium concentrations, while inputs to agricultural soils via mineral fertilisers are a major human-induced source. The EU Fertiliser Regulation (2019/1009) imposes restrictions on cadmium in fertilising products, potentially leading to a decrease in soils (EU, 2019b).

A novel method utilising LUCAS soil samples successfully modelled arsenic contamination in European soils, revealing significant variability across the continent (Fendrich et al. 2024). 1% of LUCAS samples have zinc concentrations of more than 167mg/kg (Van Eynde et al., 2023). High zinc concentrations were found not only in acid soils but also in alkaline soils with a pH above 8. The distance from zinc deposits and mines was identified as the primary anthropogenic driving factor for high zinc concentrations. Mercury has been identified close to well-known mining and metallurgical activities and chlor-alkali industries (Panagos et al., 2021).

Around 1% of the LUCAS samples have mercury concentrations higher than 429µg/kg (Ballabio et al., 2021), with land cover and temperature being the main natural drivers. Future projections indicate a positive outlook for mercury losses due to implementation of specific control technologies, reduced mining/metallurgical contamination and legally-binding regulations.

A recent analysis of individual soil samples from LUCAS in agricultural land identified among a list of metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) an important share (10-36%) of samples exceeding limit values set within the Sewage Sludge Directive (Yunta et al., 2024). For copper, results from LUCAS indicate that 1.1% of the samples should be further risk assessed, having concentrations >100mg/kg (Panagos et al., 2018). In particular, vineyards show an order of magnitude higher copper concentrations due to frequent fungicide applications (Ballabio et al., 2018). Based on a comparison between current inputs and the soil's capacity to filter and store substances, 10% of EU agricultural soils show exceedance of this capacity for copper and 2% for zinc (Römkens et al. 2024). These projections largely depend on the quality of soil monitoring data (e.g. organic matter levels, pH), statistics of applied agrochemicals and methods to define these critical limits in soil (see signal 'Heavy metals in soil ecosystems').

### *5.4.3 Outlook*

The outlook for soil pollution by metals in the EU is multifaceted, with both challenges and positive developments. Future projections offer a hopeful outlook for mercury losses and lead concentrations in soils have fallen, both because of policy interventions.

In addition, the F2F Strategy has set the target of at least 25% of the EU's agricultural land being under organic farming by 2030, which will likely help reduce the threat from certain soil pollutants. However, metals such as copper, cadmium and zinc continue to accumulate, indicating an increase of area with exceedances of soil limits in the future. This negative trend is also valid for nutrients such as nitrogen and phosphorus causing acidification and eutrophication.

The proposed SML is anticipated to significantly enhance the knowledge base about contaminants in soils and their impact on ecosystems. It encourages Member

States to act where soils are clearly unhealthy. The EU Fertiliser Regulation (EC) No 2019/1009 is expected to help in reducing cadmium levels in soils (as well as nutrient inputs) across the EU in the coming years and thus to improve the condition of ecosystems.

### *5.4.4 Sewage sludge application*

Sewage sludge is a waste product of wastewater treatment plants, and a source of organic matter and nutrients beneficial to crops. The application of sludges to agricultural soils contributes to the circular use of nutrients. However, this practice may also introduce various pollutants, such as heavy metals, organic contaminants and potential AMR resistance drivers. The management of sewage sludge is regulated in the EU by the Sewage Sludge Directive (SSD) and the revised Urban Wastewater Directive (see signal 'Long-term impacts of sludge spreading on agricultural land').

Modelling the effect of prolonged sludge application over time highlights a significant potential for soil contamination, even when it meets the metal limits set by the SSD. According to projections using the most stringent background levels of metals in soils and factoring in long-term applications of sewage sludge, there is a strong likelihood that soil health will be adversely affected. With a 10-year application of sewage sludge at a rate of 5Mgha-1, the model predicts that all agricultural soils from LUCAS 2009 database would exhibit contamination rates above 70%. This trend indicates an escalating concern for soil contamination in agricultural areas due to the use of sewage sludge, even when regulated (see Map 5.4) (Egle et al.,2023; Yunta et al., 2024).

### *5.4.5 Pesticides in EU soils*

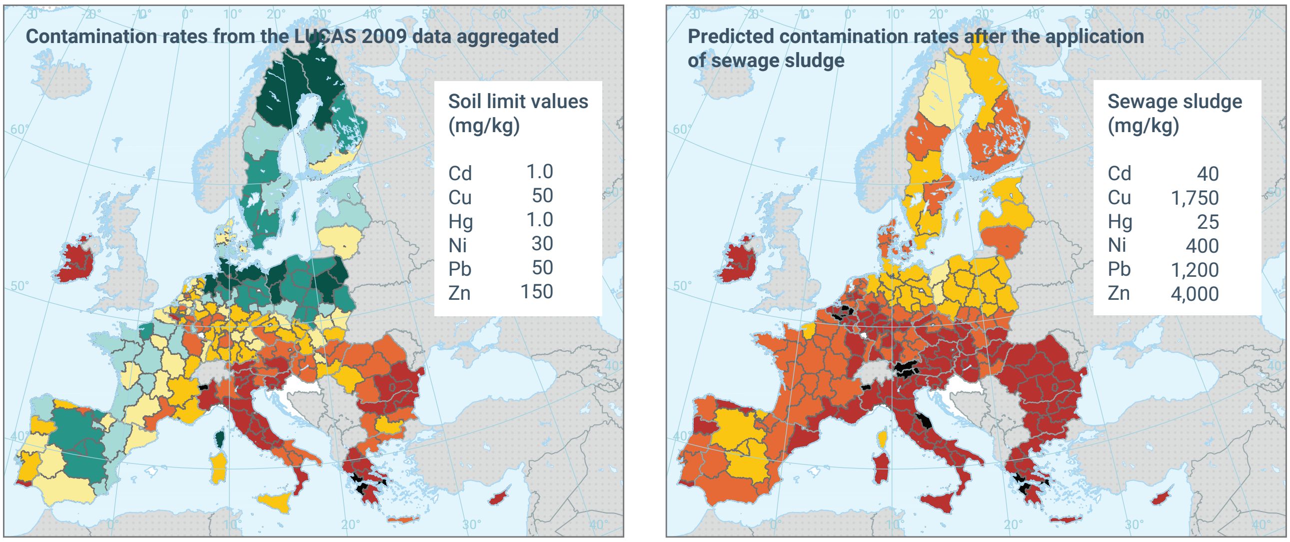
Residues of pesticides and their breakdown products (metabolites) are prevalent in agricultural soils. Pesticide residues were detected in 75% of the >3,400 LUCAS soil sites samples from 2018. Most sites (57%) showed mixtures of residues, distributed across crops and farming systems (Vieira et al, 2023) (see signal 'Pesticide residues in EU soils').

Persistent residues of pesticides banned under the Stockholm Convention on Persistent Organic Pollutants are found commonly, even in organically-managed soils. Conventionally-managed soils contain a mix of currently-used compounds (e.g. glyphosate and its main metabolite aminomethylphosphonic acid (AMPA)), as well as recently and long-banned substances such as DDT (Geissen et al., 2021; Knuth et al, 2024; Riedo et al., 2021).

Pesticide residues are present at risk-relevant levels for non-target soil organisms across EU agricultural land. In particular, the insecticides imidacloprid and chlorpyrifos as well as the fungicide epoxiconazole have been identified as main risk drivers (Franco et al., 2024). These substances were approved for use in the EU at the time of the monitoring but have since lost their approval status.

A preliminary comparison with the previous assessment (Silva et al., 2019) suggests a higher incidence of pesticide residues and a slight increase in toxicity risk in 2018 compared to 2015 (Franco et al., 2024). However, the scope of this comparison was limited, as the 2015 campaign was a pilot study for pesticides under LUCAS. Results from the 2022-2023 LUCAS survey will reveal a more robust trend analysis.

**Map 5.4** **Results of modelling the accumulation and contamination of soils by metals following sewage sludge application**




Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

**Results of modelling the accumulation and contamination of soils by metals following sewage sludge application**

Contamination rates (%)

34-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-99, Exceedance

Out side coverage

No data

Predicted contamination (%)

70, 71-80, 81-90, 91-99, Exceedance

Out side coverage

No data

0 500 1,000 1,500 km

**Notes:** The right-hand map shows the effect of the application of sewage sludge with concentration values aligned to maximal permitted application rates per Annex I B and I C of Directive 86/278/EEC, over 10 consecutive years at a sludge application rate of 5Mg/ha, starting from the actual metal concentrations observed in EU soils (left-hand map, based on LUCAS 2009 database). Soil contamination rate (%) was calculated for each of the six tested metals as the ratio between the measured or modelled metal concentration in soil and the (minimum) limit value for the corresponding metal in sewage sludge amended soils as per Annex I A of the SSD. Overall contamination rate is defined by the highest contamination rate among the six metals modelled (cadmium, copper, nickel, lead, mercury and zinc).

**Source:** Egle et al., 2023.

# 6 Key findings and conclusions

## 6.1 Key findings on pollution from production and consumption

The extraction of raw materials provides feedstock for production in the EU, yet it leads to high pollution. Between 2010-2020, emissions of major air pollutants decreased at a slower rate than in previous decades and some even increased between 2020-2021. These trends refer only to extractive activities located in the EU, although a significant proportion of material is extracted and/or processed in third countries. Initiatives to promote increased extraction of raw materials within the EU to reduce the EU's dependence on external sources will potentially lead to more pollution from this sector within the EU. However, it is also likely to result in lower overall pollution than if these materials were imported from third countries with lower environmental standards.

While emissions from industry have continued to reduce over the last decade, the health cost associated with industrial pollution remains unacceptably high and exposure to chemicals present in everyday goods remains a health concern. This highlights the urgent need to accelerate industrial transformation by improving the environmental performance of industries, accounting for their use of chemicals and resources. There is also a need to reinforce product policies to reduce substances of concern and promote clean material cycles, which is essential for advancing the circular economy. These aspects are being tackled by new policy developments, such as the revision of the Industrial Emissions Directive (IED) and initiatives promoting less harmful and more circular products in the market, like the Ecodesign for Sustainable Products Regulation (ESPR) and the proposed One Substance One Assessment Regulation. Ensuring the comprehensive implementation and effectiveness of these policies, as well as scaling up the circular economy, remains essential to meet the ZPAP targets and other environmental objectives. Regulation must play a key role in helping the EU scale up sustainable investment by providing certainty for investors and reducing greenwashing by providing common standards, e.g. in relation to green claims. This will also create the right economic incentives to prevent industrial activities relocating to outside the EU.

Waste generation rates in Europe remain high and are not aligning with the relevant zero pollution targets for 2030. Reuse of products and recovery of raw materials from waste is also hampered by the presence of hazardous substances in waste, impeding progress towards a more circular economy where recovered materials replace virgin raw materials. Waste treatment itself contributes to pollution, making waste prevention a cleaner and safer option. Therefore, further efforts are needed to prioritise waste prevention over other options, as outlined in the zero pollution hierarchy. Stronger implementation, incentives and investments are needed to reduce waste — such as by addressing food waste and packaging waste — through the revision of the Waste Framework Directive and the Packaging and Packaging Waste Directives.

Consumption levels in the EU drive the extraction of raw materials and the production of goods, eventually leading to significant waste generation. The EU consumption footprint, which includes the impacts associated with the demand for goods and services met through both EU production and supply chains and third countries — exceeds planetary boundaries. Food, housing and mobility account for more than

85% of the total environmental impacts due to their very extensive use of natural resources.

The need to address consumption to mitigate environmental impacts is increasingly recognised by EU environmental policy, as exemplified by the Single-Use Plastics Directive. Implementing the zero pollution hierarchy — i.e. prioritising the prevention of pollution over its elimination or remediation after it has occurred — will help promote demand-side policies promoting sustainable consumption and the scaling up of circular economy actions, e.g. through implementing ESPR or promoting eco-labelling.

## 6.2 Key findings on pollution impacts on human health

Good progress has been made in reducing the health impacts of air pollution in the EU, with a notable 45% decrease between 2005 and 2022 in premature deaths attributable to $PM_{2.5}$ exposure and a high likelihood of meeting the 2030 target of a 55% reduction. This is confirmed by results from the 4th Clean Air Outlook. This estimates a decline in premature deaths in 2030 of about 62-69% relative to 2005, across the scenarios modelled.

The zero pollution target of reducing premature deaths by 55% in 2030 as compared to 2005 is already achieved under baseline assumptions. This result demonstrates the impact and air quality benefits of the clean air and decarbonisation policies included in the baseline, provided they are fully implemented. However, it is crucial to sustain and accelerate this downward trend, as a notable proportion (87%) of EU residents, particularly those in urban areas, still face exposure to pollutants above the safe levels recommended by the WHO. The revision of the Ambient Air Quality Directives (EU, 2024g), aimed at aligning more closely with WHO recommendations, is a critical step towards achieving the zero pollution vision by 2050.

Exposure to harmful environmental noise levels has not significantly decreased since 2012. Meeting the 2030 target requires substantial reductions in noise levels. Additionally, emerging evidence suggests links between noise pollution and mental health illnesses as well as cardiovascular and metabolic disorders, underscoring the need to further address this issue. Projections suggest that, although a decrease in noise exposure is expected, a 30% reduction in those chronically disturbed by transport noise by 2030 is unlikely without further measures. Under optimistic scenarios with additional measures, the number of highly annoyed individuals could decrease by 23%. However, under conservative scenarios, this reduction may only reach 2%.

Efforts to improve wastewater treatment have advanced, with 81% of the EU population connected to at least secondary treatment. The revision of the Urban Wastewater Treatment Directive addresses management of micro-pollutants and microplastics, and the recast Drinking Water Directive mandates the application of methodologies developed for measuring microplastics (EU, 2024j) and monitoring PFAS. However, there remains a notable research gap concerning the long-term health and ecological impacts of microplastics, as well as their interactions with other pollutants.

Climate change exacerbates floods and droughts, compromising both water quality and availability, and posing growing threats to health. Protecting water resources from the risks of pollution is becoming increasingly important to enhance the resilience of the population and support adaptation to climate change.

Human biomonitoring data emphasise the risks of exposure to certain hazardous compounds and the necessity for further regulatory action. Fortunately, exposure to prioritised chemicals of concern has shown a decreasing trend, indicating positive progress. In some cases, however, these chemicals have been replaced with alternatives that pose similar toxicity risks. While there has been progress in reducing the use and risk of chemical pesticides and more hazardous pesticides, criticism of the methodology behind these indicators suggests additional efforts are likely needed to achieve the 50% reduction target by 2030. The withdrawal of the proposal for the Regulation on Sustainable Use of Plant Protection Products in March 2024 might slow down the progress. Existing indicators should be replaced with risk-based ones once relevant data on pesticide use become available. The establishment of an EU Early Warning System and the concept of 'safe and sustainable by design' are potential key actions to address the risk posed by harmful chemicals, ensuring faster identification of emerging risks and a shorter response time for authorities to react to these signals.

The fight against antimicrobial resistance remains a critical challenge, with the overuse or misuse of antimicrobials identified as a key driver of AMR emergence. The findings of the fourth JIACRA report confirm the associations between antimicrobial use and AMR, suggesting that further interventions to reduce the use of antimicrobials in both humans and food-producing animals would have a beneficial impact on the occurrence of AMR in bacteria from both humans and food-producing animals. Significant progress has been made in reducing veterinary antimicrobial consumption, achieving over half of the relevant zero pollution target. Conversely, human antibiotic consumption has rebounded to pre-pandemic levels, renewing concerns about AMR. The actions against AMR emphasise infection prevention, surveillance, prudent antimicrobial use and enhanced collaboration, marking a significant advancement in this area.

For soil pollution, available evidence is not conclusive as to the health risks posed by contaminants. Following the significant investment from the EU in the Soil Mission and the perspective offered by the proposed Soil Monitoring and Resilience Directive (SML), it is expected that more insights will be gained by 2030.

## 6.3 Key findings on pollution impacts on ecosystems

While there has been some progress in reducing atmospheric nitrogen deposition across the EU, significant challenges remain. Despite a 13% reduction in nitrogen deposition from 2005 to 2022, the current rate of improvement is insufficient to meet the 25% reduction target by 2030. Furthermore, rising ammonia emissions in some Member States (and limited reductions in many others) highlight the urgent need for more effective national measures against pollution from agriculture. This is confirmed by the results from the 4th Clean Air Outlook. Nearly 70% of ecosystems are estimated to remain affected by eutrophication in 2030. While this area has reduced since 2005 (by around 20%), it falls short of the targeted 25% reduction.

Conversely, advancements in abatement technologies and targeted regulations such as the IED and the former European Pollutant Release and Transfer Register (E-PRTR) Regulation ([24]) have successfully reduced heavy metal emissions. Despite significant reductions in ozone precursor emissions from 2005 to 2022, ground-level ozone levels have been maintained or even increased, with the proportion of land exceeding the target threshold value rising from 5.5% in 2020 to 32.5% in 2022 — likely, at least in part, as a result of climate impacts such as increased heat. Higher levels of ozone pollution negatively affect agricultural productivity.

([24]) Now called the Industrial Emissions Portal Regulation (EU) 2024/1244.

Water pollution from chemicals remains a significant pressure. 29% of Europe's surface waters and 77% of groundwater areas met good chemical status between 2016 and 2021, with failure to meet good status due primarily to a small number of persistent pollutants such as brominated flame retardants, mercury and PAHs. Diffuse atmospheric pollution was the most significant pressure affecting surface water bodies, and pollution from agriculture continues to exert substantial pressure on both surface and groundwater across the EU. Pesticide levels in water have remained relatively unchanged and nutrient levels in freshwater persist as a challenge.

Chemical pollution is also a significant concern in Europe's seas, where legacy pollutants like dichlorodiphenyldichloroethylene (DDE, a breakdown product of the pesticide DDT) and substances such as PFAS continue to pose ongoing risks to marine ecosystems. Although beach litter has decreased, a slight increase in microplastic releases was identified and future projections indicate that achieving reduced microplastic emission levels will be challenging. Eutrophication has slightly decreased in certain areas, but reductions are not large enough to fulfil the zero pollution objectives, while underwater noise pollution is on the rise. With small improvements in chemical pollution, eutrophication and marine litter as well as an increase in underwater noise, the EU is still not on track to meet the Marine Strategy Framework Directive's (MSFD) 'good environmental status'.

Agricultural soils are experiencing high inputs of metals, nutrients and pesticides, with the long-term application of synthetic plant production products and sewage sludge potentially adding to the challenge. Modelling reveals a concerning outlook for soil contamination, even when metal limits set by the Sewage Sludge Directive are adhered to. Pesticide residues in soils remain a threat to soil ecosystems, although regulatory restrictions strive to eliminate the most toxic ones. The EU's proposed SML establishes a harmonised soil information system, which is expected to feed targeted policies for improved soil health.

While the EU has made notable efforts to address agricultural pollution through measures such as the Nitrates Directive, increased organic farming and the ZPAP, significant challenges remain. Despite recent reductions in fertiliser use and a steady rise in organic farming, the stagnation of nitrate reduction in water and the slow decrease in ammonia emissions highlight that current measures are insufficient. This makes the achievement of the 2030 targets for reducing fertiliser consumption, nutrient losses and pesticide use difficult.

## 6.4 Key knowledge gaps

Overall, many knowledge and data gaps have been addressed since the last report. Within the report, new assessments on microplastics, a pesticides risk-based indicator for soil and studies looking into human and environmental exposures were included. Moreover, several EU legislative and non-legislative measures have been taken to close key gaps. They are provided below together with remaining or emerging knowledge gaps in various areas.

The current regulatory and monitoring framework within the EU reveals gaps in data and oversight concerning the presence of compounds of concern in both articles and waste streams. Although improvements have been made with the inclusion of a clear definition of such compounds in the Ecodesign for Sustainable Products Regulation proposal and the anticipated development of databases under the new CEAP, considerable challenges remain. The knowledge gap extends to the health impacts of human exposure to various pollutants, particularly the 'cocktail effect' arising from combined exposure to multiple chemicals. Addressing this issue is a central research focus under the Partnership for the Assessment of Risks from Chemicals (PARC) initiative, yet more comprehensive data is urgently needed. Furthermore, addressing both the negative impacts of anthropogenic noise and light on biodiversity, as well as the issue of soil contamination, continues to be a significant challenge exacerbated by the scarcity of data at the EU level. The implementation of the Kunming-Montreal Global Biodiversity Framework and the proposed SML aims to establish a robust framework to monitor and assess marine and soil health, which is a critical step forward in addressing these challenges.

Monitoring nutrient losses in the EU remains a complex challenge, partly due to the absence of a single, comprehensive indicator to assess progress effectively. This gap in measurement tools complicates the ability to evaluate the effectiveness of existing policies and practices aimed at reducing nutrient losses. Despite various initiatives and regulations targeting nutrient management, such as the EU Nitrates Directive (currently under evaluation), the fragmentation of data and indicators across different sectors and Member States limits the capacity for a cohesive and accurate assessment. Developing a unified and representative indicator is important for providing a clear picture of progress, enabling better-targeted interventions and fostering more effective policy implementation. A concerted effort towards standardising and streamlining data collection and reporting mechanisms will be essential in overcoming these challenges and advancing the EU's goals for sustainable nutrient management.

Monitoring trends in the use and risks of chemical pesticides is essential for designing effective policies and tracking progress towards objectives. However, the current pesticide risk indicators used to assess progress on this topic against zero pollution targets have been criticised for their simplistic methodology and are considered inadequate. The lack of accurate data on pesticide use limits our understanding of human exposure, including operators, local residents and the general population as well as environmental exposure.

Regarding microplastics, there are a number of gaps that need to be addressed. Monitoring programmes applying harmonised and validated methodologies are key for the assessment of the occurrence and fate of pollutants. Methodologies for drinking water and marine water are already available in the EU. Further initiatives are currently under consideration, e.g. for ground and surface water, sludge and wastewater. It should be noted that the results of environmental monitoring are not a direct indication of a pollutant's release, but of its presence in the environment and the possible exposure of humans. The proxy indicator established by the EEA (see Section 5.3, Microplastic releases to the environment) will help to better understand the release of microplastics over time. Finally, the health effects of microplastics are still poorly understood, but there is research underway to narrow this gap (such as CUSP).

Given the difficulty of reliably identifying trends, it would be helpful if raw monitoring data could be reported/made available more frequently, as proposed by the EC in 2022 for the data obtained under the WFD and its two daughter directives (Environmental Quality Standards Directive and Groundwater Directive). The use of additional monitoring techniques including remote sensing and real-time (online) monitoring using appropriate sensors as well as, monitoring strategies for key pollutants in air, water and soil could be further developed across Europe and better harmonised between Member States to obtain a more complete and consistent status of pollution in the EU in the future.

## 6.5 Conclusions and next steps

The EU is committed to advancing a holistic approach to achieving zero pollution, integrating this ambition across various strategic domains. The new EU Strategic Agenda 2024-2029 of the European Council underlines that 'our natural environment is facing increasing damage and disruption due to the triple crisis of climate change, biodiversity loss and pollution' and calls for 'making a success of the green and digital transitions' in the light of ensuring the EU's security and competitiveness and the single market while no one is left behind.

Decades of pollution-prevention action show that the EU has been able to increasingly decouple prosperity from harmful emissions and materials use. Clean technologies, e.g. in the EU's industrial production, and effective policies resulted in several success stories of pollution prevention and control over the past decades, e.g.:

a) Much better air quality through the significant reduction of air pollutant emissions by industry and other sectors. This progress is EU-wide with 97% of regions having reduced air pollution since 2016 ([25]). This has improved health and well-being while reducing healthcare expenditure, absence from work/school due to illness and also improving productivity at work. The revised Ambient Air Quality Directive (EU, 2024g) is estimated to result in net GDP gains by 2030 in the range of 0.26% to 0.44%;

b) High levels of drinking water quality and sanitation as well as safe bathing waters across the EU have been achieved through high levels of compliance with EU legislation and with financial support from the EU. Over the past three financing periods, Cohesion Policy allocations for the water sector added up to EUR 57.7 billion and citizens in the Member States that joined since 2004 also now see the same benefits;

c) Tangible plastic litter reduction for single use plastic items is a success story, not just of regulatory requirements, but also demand shift because of increased public awareness.

At the same time, some long-standing pollution problems have not been solved yet and new ones have emerged. This second edition of the Zero pollution monitoring and outlook assessment presents the latest evidence on the progress that the EU is making towards zero pollution and the perspective on achieving the targets set in 2021.

The priorities set out in the political guidelines for the European Commission 2024-2029 offer the possibility to address the identified opportunities and challenges (EC, 2024m). Key initiatives such as the Clean Industrial Deal, the Circular Economy Act, the Vision for Agriculture and Food, the Ocean Pact, the Water Resilience Strategy or the Chemicals Industry package represent major opportunities to continue driving an agenda of clean, competitive and socially fair prosperity.

The EU's zero pollution ambitions are integral to fostering competitiveness within the single market. By promoting eco-friendly innovations and sustainable business practices, the EU aims to position itself as a global leader in green technologies. This not only enhances the competitiveness of European businesses but also ensures that the single market operates in an environmentally-sustainable manner. Regulatory frameworks and incentives are being aligned to support businesses that adopt zero pollution practices, driving growth while protecting human health and the environment, and preventing biodiversity loss.

([25]) See Zero pollution regional dashboard: https://environment.ec.europa.eu/towards-zero-pollution-regions_en

Substantial investment in green infrastructure, nature-based solutions and technologies are needed for achieving zero pollution ambitions. The EU is financing growth through various mechanisms; several initiatives provide funding for projects that contribute to the zero pollution goal, such as renewable energy, sustainable transport, safe and sustainable by design chemicals and circular economy solutions. By channelling financial resources into these areas, fostering economic growth in an environmentally sustainable manner is possible. Every euro invested in nature restoration adds EUR 4 to EUR 38 in benefits while every euro invested in air pollution reduction adds at least EUR 7 in benefits. The new zero pollution dashboard for regions ([26]) can help identify progress and priorities for investment.

A key pillar of the EU's zero pollution strategy is ensuring social inclusivity. The transition to a green economy must be fair and equitable, ensuring that all residents benefit from cleaner air, soil and water. This involves supporting regions and communities that are disproportionately affected by pollution and environmental degradation as well as protecting parts of the population that are particularly vulnerable, like children, the elderly, pregnant women or individuals with pre-existing health conditions.

Many of the key findings of this assessment will be addressed in the coming years. The focus of action will turn from modernising legislation to implementation. Delivering on the many EU laws adopted in the past years ([27]) will be essential to achieving zero pollution. In some other areas, important proposals are still under negotiation ([28]) or evaluations are ongoing. Their finalisation and subsequent implementation will also be essential. Supporting the implementation will also require sustained efforts on enablers such as digitalisation, supporting regions and cities or linking pollution knowledge with other policy areas, which began with the nine flagships of the ZPAP. The zero pollution dashboard for regions and cities is one example of this work.

The main areas where new initiatives will be needed are linked to clean industry, sustainable consumption and production as well as sustaining food security, water and nature. Based on the shortcomings identified in this report, measures to reduce demand for virgin materials, including better recovery of key materials and reducing total consumption demand are critical to reduce pollution from extraction. Additionally, efforts to enhance separate collection and treatment to achieve the highest recycling standards, including for emerging waste streams, are essential for progress. This will be the purpose of a new circular economy act, helping to create market demand for secondary materials and a single market for waste, notably in relation to critical raw materials. Moreover, the EU is committed to protecting nature and reversing ecosystem degradation. Achieving further nutrient and pesticide reductions will necessitate further measures, for example, related to the sustainability of current food systems and in agricultural practices through the vision for agriculture food and the European water resilience strategy. Furthermore, continued efforts are required to further reduce emissions from key sources such as domestic heating, transport, agriculture and industry. Finally, some identified pollution challenges require more ambitious international actions. International cooperation with the European Union is needed to achieve an ambitious, legally binding plastics treaty or the establishment of a scientific policy panel for chemicals, waste and pollution.

([26]) Zero pollution regional dashboard: https://environment.ec.europa.eu/towards-zero-pollution-regions_en

([27]) A selected list of the most relevant new or revised legislation is most of the Fit for 55 package, the Ambient Air Quality Directive, the Industrial Emissions Directive, the Urban Wastewater Treatment Directive, the Nature Restoration Regulation, the Packaging and Packaging Water Directive, the Eco-design for Sustainable Products Regulation, the Water Shipment Regulation as well as the Environment Crime Directive.

([28]) E.g. the Soil Monitoring Directive, the Water Pollutants Proposal or the Pellets Regulation.

By integrating zero pollution ambitions across these strategic areas, the EU is laying the foundation for a sustainable future that combines economic growth, environmental protection and social equity. This comprehensive approach ensures that the benefits of a cleaner environment are shared by all, while maintaining the EU's position as a competitive and secure region on the global stage.

This collaborative approach is essential to safeguarding human health and preserving the environment for future generations.

# List of abbreviations

| | |
|---|---|
| AAQD | Ambient Air Quality Directive |
| AoD | Atlas of demography |
| ALAN | Artificial light at night |
| AMR | Antimicrobial resistance |
| BAT | Best available techniques |
| BAT-AEPLs | Best available techniques associated environmental performance levels |
| BAU | Business as usual |
| BDS | Biodiversity Strategy |
| BPA | Bisphenol A |
| BREF | BAT reference document |
| BWD | Bathing Water Directive |
| CAP | Common agricultural policy |
| CEAP | Circular Economy Action Plan |
| CF | Consumption footprint |
| CMR | Carcinogenic, mutagenic and reprotoxic |
| CRM | Critical raw materials |
| CSS | Chemicals strategy for sustainability |
| DF | Domestic footprint |
| DMC | Domestic material consumption |
| DWD | Drinking Water Directive |
| ECHA | European Chemicals Agency |
| EGCS | Exhaust gas cleaning systems |
| EGD | European Green Deal |
| EEA | European Environment Agency |
| EIONET | European Environment Information and Observation Network |
| EMTER | European maritime transport environmental report |

| | |
|---|---|
| END | Environmental Noise Directive |
| E-PRTR | European pollutant release and transfer register |
| ESPR | Ecodesign for sustainable products |
| ESVAC | European surveillance of veterinary antimicrobial consumption |
| EU | European Union |
| EU-OSHA | European Agency for Safety and Health at Work |
| EUROSTAT | Statistical Office of the European Union |
| EQSD | Environmental Quality Standards Directive |
| F2F | Farm to fork |
| GDP | Gross domestic product |
| GWD | Groundwater Directive |
| GTT | Green transition targets |
| HBM4EU | Human Biomonitoring for Europe |
| IED | Industrial Emissions Directive |
| IED 2.0 | Industrial and Livestock Rearing Emissions Directive |
| IEPR | Industrial Emissions Portal Regulation |
| INCITE | Innovation Centre for Industrial Transformation and Emissions |
| IPCHEM | Information platform for chemical monitoring |
| JRC | European Commission's Joint Research Centre |
| KCMD | EC Knowledge Centre for Migration and Demography |
| LCP | Large combustion plant |
| LUCAS | Land use and coverage area frame survey |
| MAP | Mediterranean action plan |
| MSFD | Marine Strategy Framework Directive |
| NEA | North-east Atlantic |
| NEC | National emission reduction commitments |
| NMVOCs | Non-methane volatile organic compounds |
| NRR | Nature Restoration Regulation |
| OSPAR | Oslo and Paris Conventions |

| | |
|---|---|
| PAHs | Polycyclic aromatic hydrocarbons |
| PARC | European partnership for the assessment of risks from chemicals |
| PCBs | Polychlorinated biphenyls |
| PFAS | Per- and polyfluoroalkyl substances |
| PFOA | Perfluorooctanoic acid |
| PFOS | Perfluorooctane sulfonic acid |
| PM | Particulate matter |
| $PM_{2.5}$ | Fine particulate matter less than 2.5μm |
| RBMP | River basin management plans |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |
| SML | Soil Monitoring Law |
| SSbD | Safe and sustainable by design |
| SUP | Single-use plastics |
| UNCCD | United Nations Convention to Combat Desertification |
| UNGA | United Nations General Assembly |
| UWWTD | Urban Waste Water Treatment Directive |
| URN | Underwater radiated noise |
| VOLY | Value of a life year |
| VSL | Value of a statistical life |
| WEEE | Waste electrical and electronic equipment |
| WFD | Water Framework Directive |
| WHO | World Health Organization |
| ZPAP | Zero pollution action plan |
| ZPMA | Zero pollution monitoring assessment |
| ZPMO | Zero pollution monitoring and outlook |

# References


Ayuso-Álvarez, A., et al., 2019, 'Association between heavy metals and metalloids in topsoil and mental health in the adult population of Spain', *Environmental Research*, 179.

Ballabio, C., Jones, A., Panagos, P., 2024, 'Cadmium in topsoils of the European Union – An analysis based on LUCAS topsoil database', *Science of The Total Environment*, 912, 168710.

Ballabio,C., Jiskra, M., Osterwalder, S., Borrelli, P., Montanarella, L., Panagos, P., 2021, 'A spatial assessment of mercury content in the European Union topsoil', *Science of The Total Environment*, 769, 144755.

Ballabio, C. et al, 2018, 'Copper distribution in European topsoils: An assessment based on LUCAS soil survey', *Science of Total Environment*, 15;636:282-298.

Bartnicka, J J., 2023, 'Lung cancer mortality and soil content of arsenic and cadmium: an ecological study in 26 EU countries', *European Journal of Public Health*, 33 (2), https://doi.org/10.1093/eurpub/ckad160.1252 accessed September 2024.

Billen, G., et al., 2024, 'Reshaping the European agro-food system and closing its nitrogen cycle: The potential of combining dietary change, agroecology, and circularity', *One Earth*, 4(6), pg. 839-850, https://doi.org/10.1016/j.oneear.2021.05.008.

Bobba, S., Carrara, S., Huisman, J., Mathieux, F., Pavel, C., 2020, *Critical Raw Materials for Strategic Technologies and Sectors in the EU, A Foresight Study, European Commission*. (DocsRoom - European Commission) accessed September 2024.

Carrara, S., et al., 2023, *Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study*, Publications Office of the European Union, Luxembourg.

Consumption Footprint Platform, 2024, https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html, accessed September 2024.

Draghi, M., 2024, *The future of European competitiveness – A competitiveness strategy for Europe* (https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en#paragraph_47059) accessed 17 October 2024.

EASA, 2025, *European Aviation Environmental Report 2025*, EASA_EAER_2025_Book_v5.pdf, accessed 25 January 2025.

EC, 2018, Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee And Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A European Strategy for Plastics in a Circular Economy (COM/2018/028 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:28:FIN).

EC, 2019a, *Environmental and health risks of microplastic pollution, Publications Office of the European Union* (https://scientificadvice.eu/advice/a-scientific-perspective-on-microplastics-in-nature-and-society) accessed 3 October 2024).

EC, 2019b, Commission Staff Working Document Fitness Check of the most relevant chemicals legislation (excluding REACH), as well as related aspects of legislation applied to downstream industries Accompanying the document Report from The Commission to the European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Findings of the Fitness Check of the most relevant chemicals legislation (excluding REACH) and identified challenges, gaps and weaknesses.(COM(2019) 264 final).

EC, 2020a, Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions EU Biodiversity Strategy for 2030 Bringing nature back into our lives (COM/2020/380 final) (EUR-Lex - 52020DC0380 - EN - EUR-Lex) accessed September 2024.

EC, 2020b, Communication from The Commission to the European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system (EUR-Lex - 52020DC0381 - EN - EUR-Lex) accessed September 2024.

EC, 2020c, Communication from The Commission to The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Region, A new Circular Economy Action Plan For a cleaner and more competitive Europe (COM/2020/98 final)( EUR-Lex - 52020DC0098 - EN - EUR-Lex) accessed September 2024.

EC, 2021a, Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil (COM/2018/028 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:28:FIN) accessed 1 September 2024.accessed 1 September 2024.

EC, 2021b, COMMISSION RECOMMENDATION on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations (C/2021/9332 final), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM%3AC%282021%299332 accessed September 2024.

EC, 2021c, Protecting seas and oceans: Commission publishes roadmap to review EU rules, European Commission, Brussels. (Commission publishes MSFD roadmap - European Commission) accessed May 2024.

EC, 2022a, Communication from The Commission to The European Parliament, the Council, The European Economic And Social Committee and the Committee of the Regions, on the monitoring framework for the 8th Environment Action Programme: Measuring progress towards the attainment of the Programme's 2030 and 2050 priority objectives (COM/2022/357 final) (eur-lex.europa.e/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0357).

EC, 2022b, Commission Recommendation of 8 December establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials (C/2022/8854) (http://data.europa.eu/eli/reco/2022/2510/oj).

EC, 2022c, Proposal for a Directive of the European Parliament and of the Council concerning urban wastewater treatment (recast) (COM/2022/541 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0541) accessed September 2024.

EC, 2022d, Proposal for a Directive of the European Parliament and of the Council amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration and Directive 2008/105/EC on environmental quality standards in the field of water policy (COM/2022/540 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0540). Accessed September 2024.

EC, 2023a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee Of The Regions on a revised monitoring framework for the circular economy (COM/2023/306 final) (EUR-Lex - 52023DC0306 - EN - EUR-Lex)accessed September 2024.

EC, 2023b, Proposal for a Regulation of the European Parliament and of the Council on preventing plastic pellet losses to reduce microplastic pollution (COM/2023/645 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:645:FIN) accessed 1 October 2024.

EC, 2023c, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M., Veeh, C., 2023, *Study on the critical raw materials for the EU 2023: final report*. Publications Office of the European Union.

EC, 2023d, Proposal for a Regulation on circularity requirements for vehicle design and on management of end-of-life vehicles. (Proposal for a Regulation on circularity requirements for vehicle design and on management of end-of-life vehicles - European Commission).

EC, 2023e, Commission staff working document impact assessment report combatting microplastic pollution in the European Union accompanying the document proposal for a Regulation of the European Parliament and of the Council on preventing plastic pellet losses to reduce microplastic pollution (SWD/2023/332 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2023:332:FIN) accessed 2 October 2024.

EC, 2023f, *EU action against microplastics*, Publications Office of the European Union (https://data.europa.eu/doi/10.2779/917472) accessed September 2024.

EC, 2023g, Proposal for a Directive on Soil Monitoring and Resilience (https://environment.ec.europa.eu/publications/proposal-directive-soil-monitoring-and-resilience_en) accessed September 2024.

EC, 2023h, Report from The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, identifying Member States at risk of not meeting the 2025 preparing for re-use and recycling target for municipal waste, the 2025 recycling target for packaging waste and the 2035 municipal waste landfilling reduction target (COM(2023) 304 final).(EUR-Lex - 52023DC0304 - EN - EUR-Lex) accessed June 2024.

EC, 2023i, Proposal for a Directive on Green Claims Details (Proposal for a Directive on green claims - European Commission) accessed September 2024.

EC, 2023j, Combatting microplastic pollution in the European Union', European Commission Staff Working Document, SWD (2023)332. (https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023SC0332) accessed September 2024.

EC, 2023k, Commission proposes 'one substance, one assessment' chemicals assessment reform for faster, simplified and transparent processes, Press Release, IP/23/6413. ('One substance, one assessment' chemicals assessment reform) accessed May 2024.

EC, 2024a, *Attitudes of Europeans towards the environment*, Eurobarometer Report, DOI: 10.2779/07854.

EC, 2024b, 'Zero Pollution Stakeholder Platform – Actions'(Actions - European Commission) accessed January 2025.

EC, 2024c, 'Green transition' (Green transition | Single Market Scoreboard) accessed September 2024.

EC, 2024d, 'EU Biodiversity Strategy Dashboard, (EU Biodiversity Strategy Dashboard), accessed 26 November 2024.

EC, 2024e, 'Monitoring Framework' (Monitoring framework - Eurostat), accessed 26 November 2024.

EC, 2024f, Industrial and Livestock Rearing Emissions Directive (IED 2.0). European Commission (https://environment.ec.europa.eu/topics/industrial-emissions-and-safety/industrial-and-livestock-rearing-emissions-directive-ied-20_en) accessed 1 October 2024.

EC, 2024g, 'European Innovation Centre for Industrial Transformation and Emissions (INCITE)', (https://innovation-centre-for-industrial-transformation.ec.europa.eu) accessed 1 October 2024).

EC, 2024h, Communication from the Commission-Guiding criteria and principles for the essential use concept in EU legislation dealing with chemicals (OJ C, C/2024/2894) http://data.europa.eu/eli/C/2024/2894/oj)

EC, 2024i, Main initiatives: Strategic Dialogue on the future of EU agriculture. (Main initiatives: Strategic Dialogue on the future of EU agriculture - European Commission)  accessed October 2024.

EC, 2024j, Commission Delegated Decision 2024/1441/EC of 11 March 2024 supplementing Directive 2020/2184/EC of the European Parliament and of the Council by laying down a methodology to measure microplastics in water intended for human consumption (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024D1441&qid=1727952143369) accessed 3 October 2024.

EC, 2024k, Commission welcomes provisional agreement for more thorough and more cost-effective urban wastewater management, Press release, IP/24/504. More thorough and cost-effective urban wastewater management accessed May 2024.

EC, 2024l, Commission welcomes international declaration on the fight against antimicrobial resistance, Press release, IP/24/4847. International declaration on the fight against AMR accessed September 2024.

EC, 2024m, *Political guidelines for the next European Commission (2024-2029)*, European Commission (https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf) accessed 17 October 2024.

EC-JRC 2024b, Environmental Footprint method. https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html accessed September 2024.

EC, 2025, Report from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions, the Fourth Clean Air Outlook, COM (2025).

ECA, 2020, Special Report 05/2020: Sustainable use of plant protection products: limited progress in measuring and reducing risks, European Court of Auditors. https://www.eca.europa.eu/en/publications?did=53001 accessed June 2024.

ECHA, 2020, *Background Document to the Opinion on the Annex XV report proposing restrictions on intentionally added microplastics*, European Chemicals Agency (https://echa.europa.eu/fr/registry-of-restriction-intentions/-/dislist/details/0b0236e18244cd73) accessed 3 October 2024.

ECHA, 2022, Per- and polyfluoroalkyl substances (PFAS), European Chemicals Agency, Per- and polyfluoroalkyl substances (PFAS) - ECHA accessed September 2024.

ECHA, 2024, *Scientific evaluation of the proposal to restrict per- and polyfluoroalkyl substances (PFAS) – Current status. September 2024 update, European Chemicals Agency*. (https://echa.europa.eu/documents/10162/67348133/upfas_evaluation_state_of_play_en.pdf/d1ad6892-e726-84a7-d2dd-74bbf8fa09af?t=1727262011016) accessed 1 October 2024.

EEA, 2019, *Healthy environment, healthy lives: how the environment influences health and well-being in Europe* EEA Report No 21/2019. (Healthy environment, healthy lives: how the environment influences health and well-being in Europe — European Environment Agency) accessed June 2024.

EEA, 2020, *State of nature in the EU, Results from reporting under the nature directives 2013-2018, EEA Report* No 10/2020, European Environment Agency. (State of nature in the EU — European Environment Agency) accessed September 2024.

EEA, 2021, *Emerging waste streams: Opportunities and challenges of the clean-energy transition from a circular economy perspective*, Briefing no. 07/2021, European Environment Agency (Emerging waste streams: Opportunities and challenges of the clean-energy transition from a circular economy perspective — European Environment Agency) accessed July 2024.

EEA, 2022a, *Zero Pollution Monitoring Assessment*, EEA Web report no. 03/2022, European Environment Agency, (Zero pollution monitoring assessment — European Environment Agency) accessed June 2024.

EEA, 2022b, *Reaching 2030's residual municipal waste target — why recycling is not enough*, Briefing no. 02/2022, European Environment Agency. (Reaching 2030's residual municipal waste target — why recycling is not enough — European Environment Agency) accessed September 2024.

EEA, 2022c, Key air quality statistics for the main air pollutants, European Environment Agency. (Air quality statistics | European Environment Agency's home page) accessed September 2024.

EEA, 2022d, Outlook to 2030 — Can the number of people affected by transport noise be cut by 30%? Briefing no. 13/2022, European Environment Agency. (Outlook to 2030 — Can the number of people affected by transport noise be cut by 30%? — European Environment Agency) accessed September 2024.

EEA, 2022e, Cross-cutting story 3: PFAS, Zero Pollution Monitoring Assessment, European Environment Agency. (Cross-cutting story 3: PFAS — European Environment Agency) accessed September 2024.

EEA, 2022f, Water Signal 1: Antimicrobial resistance, Zero Pollution Monitoring Assessment, European Environment Agency. (Water signals — European Environment Agency) accessed September 2024.

EEA, 2022g, Progress in the management of contaminated sites in Europe, European Environment Agency, Progress in the management of contaminated sites in Europe | European Environment Agency's home page, accessed June 2024.

EEA, 2023a, *Accelerating Circular Economy in Europe, State and outlook 2024*, EEA Report No, 13/2023, European Environment Agency. (Accelerating the circular economy in Europe — European Environment Agency) accessed June 2024.

EEA, 2023b, *The benefits to biodiversity of a strong circular economy*, Briefing no 10/2023, European Environment Agency (https://www.eea.europa.eu/publications/the-benefits-to-biodiversity) accessed September 2024.

EEA, 2023c, *EU exports of used textiles in Europe's circular economy*, Briefing no 01/2023, (EU exports of used textiles in Europe's circular economy — European Environment Agency) accessed September 2024.

EEA, 2023d, *Many EU Member States not on track to meet recycling targets for municipal waste and packaging waste*, Briefing no. 28/2022, European Environment Agency. (Many EU Member States not on track to meet recycling targets for municipal waste and packaging waste — European Environment Agency) accessed September 2024.

EEA, 2023e, New reuse reporting obligation. Reuse Reporting accessed September 2024.

EEA, 2023f, Combined effects of air pollution and heat exposure in Europe: time for action, European Environment Agency. Combined effects of air pollution and heat exposure in Europe: time for action | European Environment Agency's home page accessed September 2024.

EEA, 2023g, Human exposure to Bisphenol A in Europe, Briefing no 17/2023, European Environment Agency, Human exposure to Bisphenol A in Europe — European Environment Agency, accessed May 2024.

EEA, 2023h, European sea surface temperature, European Environment Agency. (European sea surface temperature | European Environment Agency's home page) accessed April 2024.

EEA, 2024a, Premature deaths due to exposure to fine particulate matter in Europe, European Environment Agency, https://www.eea.europa.eu/en/analysis/indicators/health-impacts-of-exposure-to accessed September 2024.

EEA, 2024b, Progress in the management of contaminated sites, EU Indicator framework for chemicals. (Progress in the management of contaminated sites (Indicator) | European zero pollution dashboards) accessed April 2024.

EEA, 2024c, *The costs to health and the environment from industrial air pollution in Europe – 2024 update*, Briefing No 24/2023, European Environment Agency (https://www.eea.europa.eu/publications/the-cost-to-health-and-the) accessed 1 October 2024.

EEA, 2024d, *PFAS in textiles in Europe's circular economy*, Briefing no. 11/2024, European Environment Agency, (PFAS in textiles in Europe's circular economy | European Environment Agency's home page) accessed October 2024.

EEA, 2024e, Exceedance of air quality standards in Europe, European Environment Agency. Exceedance of air quality standards in Europe | European Environment Agency's home page accessed September 2024.

EEA, 2024f, *Harm to human health from air pollution in Europe: burden of disease 2024*, Briefing no 21/2014, European Environment Agency (https://www.eea.europa.eu/en/analysis/publications/harm-to-human-health-from-air-pollution-2024) accessed 12 December 2024.

EEA, 2024g, Noise data reported under Environmental Noise Directive. (Noise data reported under Environmental Noise Directive (END)) accessed September 2024.

EEA, 2024h, *Europe's state of water 2024: the need for improved water resilience*, Report No 07/2024, European Environment Agency (https://www.eea.europa.eu/en/analysis/publications/europes-state-of-water-2024) accessed 17 October 2024.

EEA, 2024i, *European bathing water quality in 2023*, Briefing No 04/2023, European Environment Agency (https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2023) accessed 1 October 2024.

EEA, 2024j, Eutrophication caused by atmospheric nitrogen deposition in Europe, European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/eutrophication-caused-by-atmospheric-nitrogen) accessed 2 December 2024.

EEA, 2024k, *Air pollution in Europe: 2024 reporting status under the National Emission reduction Commitments Directive*, Briefing no. 07/2024, European Environment Agency (Air pollution in Europe: 2024 reporting status under the National Emission reduction Commitments Directive — European Environment Agency) accessed September 2024.

EEA, 2024l, *PFAS pollution in European waters*, Briefing No 19/2024, European Environment Agency. (PFAS pollution in European waters | European Environment Agency's home page) accessed 11 December 2024.

EEA, 2024m, Nutrients in freshwater in Europe, European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/nutrients-in-freshwater-in-europe).

EEA, 2024n, Hazardous substances in marine organisms in Europe's seas, European Environment Agency (Hazardous substances in marine organisms in Europe's seas | European Environment Agency's home page) accessed 1 October 2024

EEA, 2024o, Nutrients in Europe's transitional, coastal and marine waters. (Nutrients in Europe's transitional, coastal and marine waters | European Environment Agency's home page) accessed 1 October 2024."

EEA, 2025, Methane, climate change and air quality in Europe: exploring the connections, Briefing No 01/2025, European Environment Agency (Methane, climate change and air quality in Europe: exploring the connections | European Environment Agency's home page) accessed February 2025.

Egle, L., Marschinski, R., Jones, A., Yunta Mezquita, F., Schillaci, C. and Huygens, D., 2023, *Feasibility study in support of future policy developments of the Sewage Sludge Directive (86/278/EEC)*, Publications Office of the European Union, Luxembourg, doi:10.2760/305263, JRC134591.

Ellen MacArthur Foundation, 2019, Completing the picture: How the circular economy tackles climate change, Ellen MacArthur Foundation, Cowes, United Kingdom (https://www.ellenmacarthurfoundation.org/publications/completing-the-picture-climatechange) accessed 23 October 2023.

EMA, 2023, The European database of sales of veterinary antimicrobial agents, European Medicines Agency.

EMSA, 2021, *Study on inventory of existing policy, research and impacts of continuous underwater noise in Europe*, EMSA report EMSA/NEG/21/2020.

EMSA, 2021, *NAVISON Final Report: Calculation and analysis of shipping sound maps for all European seas from 2016 to 2050*, European Maritime Safety Agency, Lisbon (Publications - Navison - EMSA - European Maritime Safety Agency) accessed November 2024.

EMTER, 2021, *European Maritime Transport Environmental Report 2021*, EMSA, European Environment Agency. (European Maritime Transport Environmental Report 2021 — European Environment Agency) accessed May 2024.

EMTER, 2025, *European Maritime Transport Environmental Report,* EEA-EMSA Report No 15/2024.

Eriksson, U., Haglund, P., Kärrman, A., 2017, 'Contribution of precursor compounds to the release of per- and polyfluoroalkyl substances (PFASs) from wastewater treatment plants (WWTPs), Journal of Environmental Sciences, 61, pp. 80-90, https://doi.org/10.1016/j.jes.2017.05.004.

ETC/HE, 2024a, *Microplastic releases in the European Union*, ETC HE Report 2024/15, ISBN 978-82-93970-58-3.

ETC/HE, 2024b, *Development of a 2017 baseline to monitor noise under the zero pollution objectives. Methodological document*, ETC HE Report 2023/10. (ETC HE Report 2023/10: Development of a 2017 baseline to monitor noise under the zero pollution objectives. Methodological document. — Eionet Portal) accessed September 2024.

ETC/HE, 2024c, *Methodology for calculating projected health impacts from transportation noise — Exploring two scenarios for 2030*, ETC HE Report 2024/7 (https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports) accessed 22 October 2024.

ETC WMGE, 2021, *Unlocking the potential of Industry 4.0 to reduce the environmental impact of production* (https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/unlocking-the-potential-of-industry-4-0-to-reduce-the-environmental-impact-of-production) accessed 1 October 2024.

EU, 1992, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ L 206, pp. 7-50) (Directive - 92/43 - EN - Habitats Directive - EUR-Lex) accessed September 2024.

EU, 2000, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000) (Directive - 2000/60 - EN - Water Framework Directive - EUR-Lex) accessed May 2024.

EU, 2006a, Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC (OJ L 64, 4.3.2006) (EUR-Lex - 02006L0007-20140101 - EN - EUR-Lex) accessed June 2024.

EU, 2006b, Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. (OJ L 396, 30.12.2006). (Regulation - 1907/2006 - EN - REACH - EUR-Lex) accessed September 2024,

EU, 2009, Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version) (OJ L 20, pp. 7-25).(EUR-Lex - 02009L0147-20190626 - EN - EUR-Lex).

EU, 2012, Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) (OJ L 197, pp. 38–71). (Directive - 2012/19 - EN - EUR-Lex) accessed June 2024.

EU, 2013, Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy Text with EEA relevance (OJ L 226, 24.8.2013, pp. 1-17). (Directive - 2013/39 - EN - EUR-Lex)

EU, 2014, Consolidated text: Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC) (OJ L 135, 30.5.1991) (EUR-Lex - 01991L0271-20140101 - EN - EUR-Lex) accessed May 2024.

EU, 2016, Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC (OJ L 344, 17.12.2016, pp. 1-31). (Directive - 2016/2284 - EN - EUR-Lex).

EU, 2017, Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32017D0848). accessed September 2024.

EU, 2017b, Regulation (EU) 2017/852 of the European Parliament and of the Council of 17 May 2017 on mercury, and repealing Regulation (EC) No 1102/2008 (OJ L 137, 24.5.2017, pp. 1-21). (Regulation - 2017/852 - EN - EUR-Lex) accessed September 2024.

EU, 2018, Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council (OJ L 328, 21.12.2018, pp. 1-77) (Regulation - 2018/1999 - EN - EUR-Lex) accessed 26 November 2024.

EU, 2019a, Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0904).

EU, 2019b, Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003. (https://eur-lex.europa.eu/eli/reg/2019/1009/2023-03-16) accessed May 2024.

EU, 2020a, Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (http://data.europa.eu/eli/reg/2020/852/oj).

EU 2020b, Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020L2184) accessed June May 2024.

EU, 2020c, Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse (OJ L 177, 5.6.2020, pp. 32-55) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32020R0741) accessed September 2024.

EU, 2022a, Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030 (OJ L 114, 12.4.2022, pp. 22-36).

EU, 2022b, Regulation (EU) 2022/2379 of the European Parliament and of the Council of 23 November 2022 on statistics on agricultural input and output, amending Commission Regulation (EC) No 617/2008 and repealing Regulations (EC) No 1165/2008, (EC) No 543/2009 and (EC) No 1185/2009 of the European Parliament and of the Council and Council Directive 96/16/EC (OJ L 315, 7.12.2022, pp. 1-29). (Regulation - 2022/2379 - EN - EUR-Lex)

EU, 2023a, Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC (OJ L 191, 28.7.2023).(Regulation - 2023/1542 - EN - EUR-Lex)

EU, 2023b, Commission Regulation (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R2055).

EU, 2024a, Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020 (OJ L, 2024/1252, 3.5.2024) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401252)

EU, 2024b, Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste (http://data.europa.eu/eli/dir/2024/1785/oj).

EU, 2024c, Regulation (EU) 2024/1244 of the European Parliament and of the Council of 24 April on reporting of environmental data from industrial installations, establishing an Industrial Emissions Portal and repealing Regulation (EC) No 166/2006 (http://data.europa.eu/eli/reg/2024/1244/oj).

EU, 2024d, Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC (http://data.europa.eu/eli/reg/2024/1781/oj).

EU, 2024e, Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (OJ L, 2024/1991) (Regulation - EU - 2024/1991 - EN - EUR-Lex) accessed October 2024.

EU, 2024f, Regulation (EU) 2024/1157 of the European Parliament and of the Council of 11 April 2024 on shipments of waste, amending Regulations (EU) No 1257/2013 and (EU) 2020/1056 and repealing Regulation (EC) No 1013/2006 (OJ L, 2024/1157). (Regulation - EU - 2024/1157 - EN - EUR-Lex) accessed June 2024.

EU, 2024g, Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (recast).(OJ L, 2024/2881). Directive - EU - 2024/2881 - EN - EUR-Lex accessed 29 November 2024.

EU, 2024h, Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants (recast)(OJ L 169, 25.6.2019, pp. 45-77). (Regulation - 2019/1021 - EN - EUR-Lex).

European Academies Science Advisory Council, 2023, *Deep-Sea Mining: assessing evidence on future needs and environmental impacts*. (Deep-sea mining: assessing evidence on future needs and environmental impacts) accessed September 2024.

EU-OSHA, 2024, *Occupational cancer risk factors in Europe – methodology of the Workers' Exposure Survey*, European Agency for Safety and Health at Work, https://data.europa.eu/doi/10.2802/71781. accessed on September 2024.

EUROSTAT, 2024a, Material flow accounts, https://doi.org/10.2908/ENV_AC_MFA . accessed October 2024.

EUROSTAT, 2024b, GDP and main components (output, expenditure and income), https://doi.org/10.2908/NAMA_10_GDP accessed October 2024.

EUROSTAT, 2024c, Municipal waste by waste management operations, https://doi.org/10.2908/ENV_WASMUN accessed October 2024.

EUROSTAT, 2024d, Population connected to at least secondary wastewater treatment, https://ec.europa.eu/eurostat/databrowser/view/sdg_06_20/default/table?lang=en, accessed September 2024.

Falchi, F., et al., 2016, 'The new world atlas of artificial night sky brightness', *Science Advances* 2(6), e1600377.

Fendrich, A.N., et al., 2024, 'Modeling arsenic in European topsoils with a coupled semiparametric (GAMLSS-RF) model for censored data', *Environment International*, 185,108544.

Franco et al., 2024, 'Evaluation of the ecological risk of pesticide residues from the European LUCAS Soil monitoring 2018 survey', *Integrated Environmental Assessment and Management*, 20(5), pp. 1639-1653.

Galimberti, F., Bopp, S., Carletti, A., et al. 2024, 'From parcels to people: development of a spatially explicit risk indicator to monitor residential pesticide exposure in agricultural areas. (https://doi.org/10.21203/rs.3.rs-4568803/v1).

GESAMP, 2016, *Sources, fate and effects of microplastics in the marine environment: part two of a global assessment*, (Kershaw, P.J., and Rochman, C.M., eds). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/

Geissen, V., et al., 2021, 'Cocktails of pesticide residues in conventional and organic farming systems in Europe – Legacy of the past and turning point for the future', *Environmental Pollution*, 278, 116827 https://doi.org/10.1016/j.envpol.2021.116827.

Grizzetti, B., et al., 2023, *Knowledge for Integrated Nutrient Management Action Plan (INMAP)*, Publications Office of the European Union, Luxembourg, (https://publications.jrc.ec.europa.eu/repository/handle/JRC129059). Accessed 26 November 2024.

Grizzetti, B., et al., 2024, Effects of EU policy and climate change on future delivery of nutrients to European seas, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-14412, https://doi.org/10.5194/egusphere-egu24-14412.

HELCOM, 2023, State of the Baltic Sea 2023, Third HELCOM holistic assessment 2016-2021. (State-of-the-Baltic-Sea-2023.pdf) accessed May 2024.

HBM4EU, 2022a, *Policy Brief for Mercury*, European Human Biomonitoring Initiative.

HBM4EU, 2022b, *Policy Brief for Lead*, European Human Biomonitoring Initiative.

HBM4EU, 2022c, *Policy Brief Chromium VI*, European Human Biomonitoring Initiative.

HBM4EU, 2022d, *Policy Brief for Inorganic arsenic*, European Human Biomonitoring Initiative.

Hölker, F., et al., 2023, 'Light pollution of freshwater ecosystems: principles, ecological impacts and remedies', *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 18;378(1892):20220360.

IIASA, 2023, Analysis of air pollutant emission trends for EU energy intensive industry sectors final report (https://circabc.europa.eu/ui/group/06f33a94-9829-4eee-b187-21bb783a0fbf/library/e2ad5837-5af4-4df2-aca6-d7944f4e8d3b) accessed: 1 October 2024.

Jägerbrand A.K. and Spoelstra K. 'Effects of anthropogenic light on species and ecosystems', *Science 380*, pp. 1125-1130.

JRC, 2013, *Guidance on Monitoring of Marine Litter in European Seas, A guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive*, Joint Research Centre. (Guidance on Monitoring of Marine Litter in European Seas) accessed May 2024.

JRC, 2022, *Zero pollution outlook 2022*, Joint Research Centre, Publications Office of the European Union, Luxembourg, doi:10.2760/39491, JRC129655.

JRC-ESDAC, 2022, LUCAS 2018 TOPSOIL data, Joint Research () Centre, European Soil Data Centre. (LUCAS 2018 TOPSOIL data - ESDAC - European Commission).

JRC, 2024, MSFD Technical Group on Marine Litter, Hanke, G., Walvoort, D., Ruiz-Orejón, L. F., van Loon, W. M. G. M., Giorgetti, A., Molina-Jack, M. E., Vinci, M., European Coastline Macro Litter Trends 2015–2021, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/0752301, JRC138907.

Klinnert, A., Barbosa, A.L., Catarino, R. et al., 2024, 'Landscape features support natural pest control and farm income when pesticide application is reduced' Nature Communications, 15(5384) (https://doi.org/10.1038/s41467-024-48311-3).

Knuth, D., 2024 'Pesticide residues in organic and conventional agricultural soils across Europe: measured and predicted concentrations', Environmental Science and Technology, 58, pp.6744–6752. https://doi.org/10.1021/acs.est.3c09059

Leip, A., at al., 2022, 'Halving nitrogen waste in the European Union food systems requires both dietary shifts and farm level actions', *Global Food Security* 35, p. 100648.

Lusher, A.L., et al., 2017, Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety, FAO Fisheries and Aquaculture Technical Paper No 615 (https://openknowledge.fao.org/server/api/core/bitstreams/a9a298e0-9db6-4769-beac-37325be3e280/content) accessed 3 October 2024.

Nicolopoulou-Stamati P., et al., 2016, 'Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture, *Frontiers in Public Health*, 4. https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2016.00148.

OECD, 2019, *Global Material Resources Outlook to 2060 Economic Drivers and Environmental Consequences Report*, OECD Publishing, Paris, (https://doi.org/10.1787/9789264307452-en) accessed June 2024.

OSPAR, 2023a, *Hazardous Substances Thematic Assessment*, Quality Status Report 2023. OSPAR Commission, London (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/hazardous-substances) accessed May 2024.

OSPAR, 2023b, *Eutrophication Thematic Assessment, Quality Status Report 2023*, OSPAR Commission, London. (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/eutrophication/) accessed May 2024.

OSPAR, 2023c. *Marine Litter Thematic Assessment. Quality Status Report 2023*. OSPAR Commission, London. (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/marine-litter) accessed May 2024.

OSPAR, 2023d, *Underwater Noise Thematic Assessment, Quality Status Report 2023*. OSPAR Commission, London. (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/underwater-noise) accessed May 2024.

Panagos et al. 2024, 'How the EU Soil Observatory is providing solid science for healthy soils', *European Journal of Soil Science*, 75(3), e13507.

Panagos, P., Jiskra, M., Borrelli, P., Liakos, L., Ballabio, C., 2021, 'Mercury in European topsoils: Anthropogenic sources, stocks and fluxes', *Environmental Research*, 201, 111556.

Panagos, P., Ballabio, C., Lugato, E., Jones, A., Borrelli, P., Scarpa, S., Orgiazzi, A., & Montanarella, L., 2018, 'Potential Sources of Anthropogenic Copper Inputs to European Agricultural Soils', *Sustainability*, 10(7), 2380. https://doi.org/10.3390/su10072380

Pasqualino, R., Valenzano, A., Chiorrini, A., Wierzgala, P., Frankowska, A., Sanyé-Mengual, E., Bennett, M., Listorti, G., Sala, S., 2025, *Consumption Footprint and Domestic Footprint Outlook report 2024: projections up to 2030 in the frame of the Zero Pollution Action Plan*. Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/6552881, JRC139655.

Pistocchi, A. et al., 2022, 'European scale assessment of the potential of ozonation and activated carbon treatment to reduce micropollutant emissions with wastewater, *Science of The Total Environment*, 848 (157124) https://doi.org/10.1016/j.scitotenv.2022.157124 accessed September 2024.

Quaranta, E., et al., 2022, 'A hydrological model to estimate pollution from combined sewer overflows at the regional scale: Application to Europe', *Journal of Hydrology: Regional Studies*, 41(101080).

Riedo, J., 2021, 'Widespread occurrence of pesticides in organically managed agricultural soils — the ghost of a conventional agricultural past?' *Environmental. ScienceandTechnology*, 55 (5), 2919–2928. https://doi.org/10.1021/acs.est.0c06405.

Römkens, P. F. A. M. et al., 2024, *Balances and Critical Concentrations for nutrients and metals in Arable Soils in the EU*, Wageningen Environmental Research (WENR), Report of the European Topic Centre Data Integration and Digitisation (ETC/DI).

Sala, S., Crenna, E., Secchi, M., Sanyé-Mengual, E., 2020, 'Environmental sustainability of European production and consumption assessed against planetary boundaries', *Journal of Environmental Management*, 269, 110686. (https://www.sciencedirect.com/science/article/pii/S0301479720306186) accessed September 2024.

Sanyé-Mengual, E., Secchi, M., Corrado, S., Beylot, A., Sala, S., 2019, 'Assessing the decoupling of the environmental impacts of EU-28 consumption from GDP', *Journal of Cleaner Production*, 236, 117535. (https://www.sciencedirect.com/science/article/pii/S0959652619323431) accessed September 2024.

Sanyé-Mengual, E., Pasqualino, R., Omodara, L., Frankowska, A., Wierzgala, P., Chiorrini, A., Bennett, M., Listorti, G., Sala, S., 2024, *Consumption Footprint and Domestic Footprint Monitoring report 2025: update in methodology, data and policy uses*. Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/4133548, JRC138470.

Schwab, K., 2017, The fourth industrial revolution. World Economic Forum. Crown Business. ISBN: 978-1-5247-5886-8.

Soares, J., Plass, D., Kienzler, S., González Ortiz, A., Gsella, A., Horálek, J., 2023, Health Risk Assessment of Air Pollution: assessing the environmental burden of disease in Europe in 2021 (Eionet Report – ETC HE 2023/7). European Topic Centre on Human Health and the Environment.

Silva, S.; et al., 2019, 'Pesticide residues in European agricultural soils – A hidden reality unfolded', *Science of The Total Environment*, 653, pp.1532-1545. https://doi.org/10.1016/j.scitotenv.2018.10.441. accessed May 2024.

Silva et al., 2023, 'Pesticide residues with hazard classifications relevant to non-target species including humans are omnipresent in the environment and farmer residences', *Environment International*, 181.

Tasker, M. L., 2016, 'How might we assess and manage the effects of underwater noise on populations of marine animals?', *Advances in Experimental Medicine and Biology*, Springer.

Tavares, P., et al., 2021. 'Reviewing the Role of Outdoor Lighting in Achieving Sustainable Development Goals', *Sustainability* 13 (22), p. 12657.

Thunis, P., et al., 2023, *Urban $PM_{2.5}$ Atlas, Air Quality in European Cities, 2023 Report*, Publications Office of the European Union, Luxembourg.

UNEP, 2024, *Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes*. International Resource Panel. Nairobi, United Nations Environment Programme.

UNEP, 2022, Convention on Biodiversity, Kunming-Montreal Global Biodiversity Framework, Target 7, United Nations Environment Programme. (https://www.cbd.int/gbf/targets/7) accessed on 10 October 2024.

UNEP-MAP, 2023, The 2023 *Mediterranean Quality Status Report and a Renewed Ecosystem Approach Policy in the Mediterranean*, Decision IG.26/3, UNEP/MED IG.26/22.(23ig26_22_2603_eng.pdf) accessed May 2024.

UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 93, 220 p.

Van Eynde, E., Fendrich, A.N., Ballabio, C, Panagos, P., 2023, 'Spatial assessment of topsoil zinc concentrations in Europe', Science of The Total Environment, 892,164512.

Vieira, D., Franco, A., De Medici, D., Martin Jimenez, J., Wojda, P., Jones, A.,2023, *Pesticides residues in European agricultural soils — Results from LUCAS 2018 soil module, Publications* Office of the European Union, Luxembourg, doi:10.2760/86566, JRC133940.

Vieira, D.C.S., et al., 2024, 'Soil pollution in the European Union – An outlook', Environmental Science & Policy, 161, p. 103876.

WHO Europe, 2018, *Environmental noise guidelines for the European region*, World Health Organization Regional Office for Europe, Copenhagen (https://www.who.int/europe/publications/i/item/9789289053563) accessed 6 October 2022.

WHO, 2021, *WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and $PM_{10}$), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization. https://iris.who.int/handle/10665/345329 Accessed September 2024.

WHO, 2022, Fact Sheet for Arsenic. Online article: Arsenic (who.int) accessed 20 September 2024.

WHO, 2023a, Air pollution: The invisible health threat. Air pollution: The invisible health threat accessed September 2024.

WHO, 2023b, *Climate change, pollution and health, Impact of chemicals, waste and pollution on human health*, EB154/24. (Climate change, pollution and health - Impact of chemicals, waste and pollution on human health) accessed September 2024.

Yunta, F., et al., 2024, Quantitative analysis of the compliance of EU Sewage Sludge Directive by using the heavy metal concentrations from LUCAS topsoil database, *Environmental Science & Pollution Research*.

**European Environment Agency and Joint Research Centre**

**Zero pollution monitoring and outlook 2025** — 125 pp. — 21 x 29.7 cm

ISBN: 978-92-9480-691-8
doi: 10.2800/6470682

European Environment Agency

European Commission

Publications Office of the European Union

TH-01-24-015-EN-N
doi:10.2800/6470682