# RISK MANAGEMENT AND EMISSIONS REDUCTION OF FOUR UV-LIGHT STABILISERS

## Report

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# EXECUTIVE SUMMARY

***Introduction***

UV-light stabilisers are a class of additives incorporated into materials, primarily polymers, to extend the lifespan of end-products by protecting the polymer from the damaging effects of UV radiation.[1,2] They are used ubiquitously in the European Union (EU) in industrial, professional and widespread consumer uses across a range of different sectors. This report focuses on four UV-light stabilisers:

- 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol (UV-329, CAS# 3147-75-9),
- 2-(2'-hydroxy-3'-tert-butyl-5'-methylphenyl)-5-chloro benzotriazole (UV-326, CAS# 3896-11-5),
- 2-(2H-benzotriazol-2-yl)-4,6-bis(2- phenyl-2-propanyl)phenol (UV-234, CAS# 70321-86-7), and
- 2-(2H-benzotriazol-2-yl)-4-methylphenol (UV-P, CAS# 2440-22-4).

All substances are manufactures and imported between 1,000 – 10,000 tonnes per annum in the EU.[3] This report aims to identify the **industrial and professional uses** of UV-light stabilisers, and to assess the baseline emissions to the environment during the manufacture of products that contain UV-326, UV-329, UV-234 and/or UV-P, in the context of recommended regulatory action documented in the Assessment of Regulatory needs (ARN) published in 2024.[4]

Similarly, this report explores the current state of the art with respect to risk management measures (RMMs) that are used to abate the emissions of UV-light stabilisers during these manufacturing processes, as well as exploring future risk management measures that may be implemented subsequently to further reduce emissions.

***Regulatory context***

According to published regulatory reports, UV-light stabilisers are emitted to the environment following releases from the production of plastic articles at industrial sites, the finishing of plastic articles by professionals, as well as the indoor and outdoor use of rubber/ plastic articles by both professionals and consumers.[5] Emissions of these substances are influenced by how the UV-light stabilisers are incorporated into polymers, and the relevant manufacturing processes. For example, when stabilisers are bound into a polymer matrix, they are strongly embedded within the material and, depending on the exact properties of the substance and matrix, can diffuse slowly through the polymer matrix and subsequently be released to the environment. Conversely, UV stabilisers that are not bound into a solid matrix, such as the use in cosmetic or personal care products, cleaning sprays or liquid formulations (e.g., biocides, coatings before application, ) are freely available at the surface and can lead to comparatively higher volumes of releases to the environment.[6]

In 2022, the German Competent Authority (BAuA, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) published the conclusions of a Regulatory Management Options Analysis for UV-326, UV-329, UV-234 and UV-P (as well as UV-928, not in scope), based on the potential hazardous properties of these substances. It indicated that the best course of regulatory action was to prepare an Annex XV dossier under Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)[7] (SVHC, substance of very high concern) for UV-326, UV-234 and UV-329, and to prepare an Annex VI dossier under the Classification, Labelling and Packaging (CLP) Regulation for UV-P (Aquatic Chronic 1, H410,

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[1] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type, By End-Use Industry, and Regional Forecast, 2025-2032. Available at: [UV Stabilizers Market Size & Share | Global Report [2032]]

[2] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: [Plastic Additives | OECD]

[3] European Chemicals Agency. ECHA Chemicals Database. Available at: [ECHA CHEM] [accessed August 2025]

[4] European Chemicals Agency (2024). Assessment of Regulatory Needs – Hydroxyphenyl Benzotriazoles. Available at: 84bc6c58-9d3d-f7d7-3d11-00fb4c0e41ae

[5] European Chemicals Agency (2024). Assessment of Regulatory Needs – Hydroxyphenyl Benzotriazoles. Available at: 84bc6c58-9d3d-f7d7-3d11-00fb4c0e41ae

[6] Chen *et al.* (2024). Benzotriazole ultraviolet stabilizers in the environment: A review of occurrence, partitioning and transformation, *Science of the Total Environment*, 954, 176362. Available at: https://doi.org/10.1016/j.scitotenv.2024.176362

[7] European Commission (2006). 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 (Text with EEA relevance)Text with EEA relevance. Available at: https://echa.europa.eu/regulations/reach/legislation

M=10).[8] In December 2023, UV-326 and UV-329 were added to the Candidate List based on their vPvB (very persistent, very bioaccumulative) properties.[9] In June 2025, the UV-P proposed classification was adopted.[10]

In 2024, the European Chemicals Agency (ECHA) published an Assessment of Regulatory Needs (ARN) for hydroxyphenyl benzotriazoles, including UV-326, UV-329, UV-234 and UV-P. It indicated a range of proposed regulatory actions, including a potential restriction under REACH. The justification for further regulatory action noted that releases from the environment occur from consumer and widespread professional uses, that are often non-contained and cannot be avoided.

Consumer uses were identified by reviewing registration data under REACH and include adhesives and sealants, air care products, anti-freeze products, disinfectants and cleaning products, coatings and paints, metal surface treatment products, inks and toners, perfumes and fragrances, and cosmetics and personal care products. The ARN noted the following sectors where releases to the environment cannot be avoided: washing and cleaning products, cosmetics and personal care products, perfumes and fragrances, adhesives and sealants, and consumer use of coatings and paints.[11]

***Industrial and professional uses***

This Study focuses on industrial and professional uses of UV-light stabilisers. An in-depth review of the literature was conducted to identify uses of the substances in scope of this assessment, supplemented by stakeholder engagement. The Table below provides a summary of the uses identified in this assessment, at the substance and sector level. These are explored in more detail in the body of the report.

Table 1-1: Summary of identified uses.

| Sector | UV-326 | UV-329 | UV-234 | UV-P |
|---|---|---|---|---|
| **Adhesives and sealants** | x | x | x | x |
| **Building and construction** | x | x | x | x |
| **Coatings, paints and inks** | x | x | x | x |
| **Electronics** | x | x | x | x |
| **Mobility and automotive** | x | x | x | X |
| **Packaging** | x | x | x | x |
| **Renewable energy** | | | x | |
| **Sports equipment** | x | | x | |
| **Textiles and fibres** | x | | x | x |
| **Wire and cable** | x | x | x | |

***Baseline emissions***

This report estimates the annual emissions to air and water, at the sectoral and substance level, that may arise as a result of the manufacture of the products in scope in the EU-27. This emissions analysis is scenario-based, with emission release factors (ERFs) derived from publicly available REACH data, namely the OECD Emission Scenario Document on Plastic Additives and specific Environmental Release Categories (spERCs) for the adhesives and coatings sectors. In the absence of specific industry data, scenario-based analysis was conducted to model emissions to air and water at increments across the tonnage band: 1,000, 2,500, 5,000, 7,500 and 10,000.

For the sectors in scope, the central emissions estimate for the 5,000 tonnes scenario is reported below for all substances combined. The largest estimated emissions were for the adhesives and sealants, and coatings paints and inks sectors. The lowest emissions were observed for the packaging and electronics sectors, with

[8] European Chemicals Agency (2022). Regulatory Management Option Analysis Conclusion Document for UV-329, UV-326, UV-234, UV-P, UV-928. Available at: RMOA_Conclusion_Doc_v2_20141010.docx

[9] European Chemicals Agency (2023). Inclusion of substances of very high concern in the Candidate List for eventual inclusion in Annex XIV. Available at: 05ea7d09-6615-9ac3-be76-5c9cd96b8eb7

[10] European Chemicals Agency. Registry of CLH intentions until outcome – UV-P. Available at: Registry of CLH intentions until outcome - ECHA

[11] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: 309919c8-feff-284a-bea3-0ed65a61e7de ; ECHA CHEM – ECHA Chemicals Database. Available at: ECHA CHEM [date accessed 05.09.2025]

marginally higher emissions estimated for the building and construction, mobility and automotive, and textiles and fibres sectors. These emissions are summarised at the EU-27 and local level, below.

Table 1-2: Summary of aggregated emissions of all substances at the EU-27 (tonnes per year) and local (grams per day) level; assumes 'worst-case scenario' emissions with no Risk Management Measures applied from the '5,000 tonnes scenario'.

| Sector | EU-27 level emissions: tonnes per year (aggregated emissions of all substances) | | Local level emissions: grams per day (aggregated emissions of all substances) | |
|---|---|---|---|---|
| | Air | Water | Air | Water |
| **Adhesives and sealants** | 0.90 | 5.25 | 24.0 | 144.0 |
| **Building and construction** | 0.09 | 0.09 | 2.2 | 1.5 |
| **Coatings, paints and inks** | 0.66 | 5.17 | 20.0 | 140 |
| **Electronics** | 0.03 | 0.03 | 0.7 | 0.7 |
| **Packaging** | 0.06 | 0.06 | 1.7 | 1.7 |
| **Renewable energy** | 0.02 | 0.02 | 0.4 | 0.4 |
| **Textiles** | 0.03 | 0.03 | 9.7 | 0.7 |
| **Sports equipment** | 0.06 | 0.06 | 1.6 | 1.6 |
| **Wire and cable** | 0.02 | 0.02 | 0.5 | 0.5 |

The emissions estimated in this report are expressed as total amounts emitted from the relevant industries. Subsequent treatment or dilution in surface water and partitioning to suspended matter or sediment has not been estimated and neither the potential emissions to soil due to the application of treated sludge to land for agricultural purposes.

When considering emissions from all sectors combined, the analysis suggests that no single UV substance dominates emissions to the environment, and that differences between sectors (i.e., volumes of use, manufacturing processes) are the determining factor. Emissions to water are the primary driver of release, with volumes being approximately 6x higher for the adhesives and coatings sectors compared to emissions to air. Similarly, calculated emissions at the local level (as a proportion of the annual, regional emissions) are estimated to be in the order of grams per day. Assuming 'worst-case scenario' emissions with no Risk Management Measures applied, total estimated emissions to the environment (air and water combined) equates to 12.6 tonnes, or 0.25% of all emissions from the 5,000 tonnes scenario.

Conversely, emissions to environmental compartments were found to be lowest for applications where the UV-light stabiliser is bound into a solid polymer matrix following the masterbatch process. This decreases the likelihood of uncontrolled release during conversion processes, with environmental releases being further reduced by enhanced encapsulation technologies.[12] If releases occur, these may most likely be in the polymer form and therefore disposed as solid waste.

The Study's methodology and data constraints prevent the exact determination of EU-27 and local-level emissions. The reported emissions figures are expected to be an overestimate as the report assumes 100% of tonnage is used in scoped applications, default Emission Release Factor (ERF) values are used that do not account for site-level controls, and does not account for stabilisers being embedded in polymer matrices (which reduces uncontrolled release and often leads to disposal as solid waste). Therefore, these figures should be considered conservative and a 'worst case scenario'.

***Risk Management Measures***

Risk management measures, or engineering controls and techniques, are used in manufacturing processes to provide systemic, reliable and often cost-effective methods for reducing environmental emissions of chemicals. This Study has identified several measures used to reduce overall environmental emissions that can be considered industry standard. These are: local exhaust ventilation (LEV); solid-separators, industrial (on-site) wastewater treatment plants; sewage sludge (relevant for indirect releases to the soil compartment) and wastewater incineration; technical considerations (e.g., usage of closed containers/production vessels),

[12] Number Analytics (2025). Unlocking UV Stability in Polymers. Available at: Unlocking UV Stability in Polymers

their use when bound into a polymer matrix, as well as industrial uses being confined to indoor conditions (thus minimising direct emissions to air, water, sediment and soil).

These measures have high removal efficiencies, from 50% to 100% (e.g., sewage sludge and wastewater incineration, exhaust air filtration), and are thus expected to significantly reduce the environmental emissions that may arise during the manufacture of the substances in scope of this Study. In addition, a range of further measures, which can be regarded as industry standard, were identified and are expected to already be in place. If those that have not yet implemented any of these RMMs should take action to do so, emissions to all environmental compartments can be significantly reduced. The measures include physical (e.g., distillation), physico-chemical (e.g., adsorption), electro-physical (e.g., wet electrostatic precipitator), chemical (e.g., alkaline scrubber), mechanical (e.g., separation) and biological (e.g., activated sludge treatment) measures that may be used in isolation or in tandem.

***Conclusion and suggestions for future work***

UV-light stabilisers are used ubiquitously worldwide across a wide range of important sectors. This Study focused on EU-27 only. As exact estimates of baseline emissions to the EU-27 that arise from the manufacture of the products in scope were not available, scenario-based modelling has been used to demonstrate that emissions at the local level are estimated to be in the region of grams per day, likely driven by the low volatility of UV-light stabilisers that are primarily bound into a polymer matrix, and products that are converted using closed processes.

With regard to future work, when considering regulatory action for a substance, or group of substances, the exact uses and manufacturing processes should be considered on a case-by-case basis. Precedent could be drawn from the draft restriction proposal published July 18, 2025, by the French authority ANSES.[13] Octocrilene (CAS #6197-30-4, EC# 228-250-8) is widely used in EU as a UV filter, stabiliser and solubilizer. It is considered toxic for the environment and potentially persistent but not bioaccumulative, toxic to reproduction and potentially an endocrine disruptor for the environment. ANSES concluded: "*As no risks were identified from the preparations containing octocrilene as additive (e.g. paints, adhesives…), the production of plastic articles, inclusion into a matrix, the wide dispersive use of plastics and the service life of plastic, these uses are not substantiated anymore in the dossier*." In addition, it is stated that "*the main driver for the identified risks is the wide dispersive use of finished cosmetic products*". As a conclusion, ANSES is proposing a restriction for Octocrilene in finished cosmetic products only.[14] These insights may be relevant when considering further regulatory action for UV-light stabilisers and their use as plastic additive.

The results presented in this Study demonstrate that emissions from industrial and professional uses of UV light stabilizers are adequately controlled, or could be managed through appropriate RMMs. Emissions from consumer uses were not investigated in this report. Following a review of the literature, this may warrant further investigation to determine whether releases from consumer uses pose an environmental risk.

[13] European Chemicals Agency (2025). Annex XV Restriction Report for Octocrilene. Available at: Annex XV restriction format with instructions

[14] European Chemicals Agency (2025). Annex XV Restriction Report for Octocrilene. Available at: Annex XV restriction format with instructions

# CONTENTS


1. INTRODUCTION 7
   1.1 UV-LIGHT STABILISERS 7
   1.2 REGULATORY CONTEXT 7
      1.2.1 Environmental releases 8
   1.3 AIMS 9
   1.4 SCOPE 10
      1.4.1 Geographical and temporal scope 10
      1.4.2 Chemical and sectoral scope 10
   1.5 METHODOLOGY AND LIMITATIONS 10
      1.5.1 Overview of the methodology 10
      1.5.2 Assumptions and limitations 11
   1.6 ORGANISATION OF THE REPORT 12
2. BASELINE – USES AND EMISSIONS 13
   2.1 USE MAPPING 13
      2.1.1 Sectoral uses 14
   2.2 MANUFACTURING PROCESSES AND POTENTIAL EMISSION RELEASES 17
      2.2.1 Production of masterbatches 17
      2.2.2 Production of finished articles 18
      2.2.3 Summary 21
   2.3 ALLOCATION OF SUBSTANCE TONNAGES AND SECTORAL MARKET SHARE 22
      2.3.1 Data sources 22
      2.3.2 Tonnage estimates per substance 23
      2.3.3 Market share allocation per sector and per substance 23
   2.4 BASELINE EMISSIONS FROM THE MANUFACTURE OF PRODUCTS CONTAINING UV-LIGHT STABILISERS 24
   2.5 RISK MANAGEMENT MEASURES 29
      2.5.1 Local exhaust ventilation 30
      2.5.2 Industrial (on-site) wastewater treatment plant 30
      2.5.3 Wastewater incineration 31
      2.5.4 Other identified measures 31
3. POTENTIAL RISK MANAGEMENT MEASURES AND EMISSIONS REDUCTION 32
      3.1.1 Wastewater 32
      3.1.2 Air 34
      3.1.3 Conclusions on the potential risk management measures 36
4. CONCLUSIONS 37


# Appendices


APPENDIX 1 METHODOLOGY 40
APPENDIX 2 IDENTIFIED USES AND SUBSTANCE MAPPING 49
APPENDIX 3 DETAILED EMISSIONS ESTIMATES 54
APPENDIX 4 PHYSICO-CHEMICAL PROPERTIES OF UV-LIGHT STABILISERS 61

# 1. INTRODUCTION

## 1.1 UV-LIGHT STABILISERS

UV-light stabilisers are a class of additives incorporated into materials, primarily polymers, to extend the lifespan of end-products by protecting the polymer from the damaging effects of UV radiation.[15,16] These additives absorb, reflect and disperse UV radiation before it damages the material.[17] Organic stabilisers, such as benzotriazoles and hindered amine light stabilisers absorb UV radiation and convert it to heat energy, where it is dispersed at a less harmful (longer) wavelength to the surrounding environment. The substances in scope of this assessment are benzotriazoles.

Prolonged exposure to UV radiation can cause discolouration, loss of mechanical properties, cracking and, ultimately, a shorter product lifespan. They are particularly beneficial for use in outdoor products that are continuously exposed to UV radiation, such as car parts, outdoor stadium seats, playground equipment and in construction materials (list not exhaustive). However, their use in indoor products is also advantageous, as products can still be exposed to sunlight and external sources of UV radiation, for example indoor radiation from fluorescent strip lighting.[18]

According to published reports, the global UV-light stabilisers market has been valued at $1.56 billion in 2024 (approx. €1.35 billion[19]) and is projected to grow to $2.41 billion (€2.1 billion) by 2032.[20] The sector with the largest market share for UV-light stabilisers is plastics and polymers, using these substances in products such as automotive components, construction materials, packaging materials, as well as to a lesser extent in adhesives, sealants, and coatings. Reports of the exact market share of each sector, and the largest reported sectors, vary between each source.[21] The market share of each sector is further explored in Section 2.3.3 and Appendix 1 of this report.

UV-light stabilisers were originally developed for use in polymers, plastics and coatings because their properties protect materials from light induced degradation. However, they are now also widely used in consumer products such as air care products, antifreeze products, disinfectants and cleaning products, perfumes and fragrances, and cosmetics and personal care products.[22] Table 2-1 in Section 2.1 lists the uses registered for UV-light stabilisers under REACH, with key consumer uses including adhesives and sealants, coatings and paints, metal surface treatment products, inks and toners, and consumer uses named above.[23]

## 1.2 REGULATORY CONTEXT

In 2022, the German Competent Authority (BAuA, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) published the conclusions of a Regulatory Management Options Analysis (RMOA) for:

- 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3- tetramethylbutyl)phenol (UV-329),
- 2-(2'-hydroxy -3' -tert-butyl-5'- methylphenyl)-5-chloro benzotriazole (UV-326),
- 2-(2H-benzotriazol-2-yl)-4,6-bis(2- phenyl-2- propanyl)phenol (UV-234),

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[15] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type, By End-Use Industry, and Regional Forecast, 2025-2032. Available at: UV Stabilizers Market Size & Share | Global Report [2032]

[16] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[17] WellTChem (2023). How does a light stabiliser work? Available at: How does a light stabilizer work? | welltchem.com

[18] Cole-Parmer. UV Properties of Plastics: Transmission and Resistance. Available at: coleparmer.com/tech-article/uv-properties-of-plastics

[19] European Commission. Exchange rate (InforEuro). Available at: InforEuro, the exchange rate of the Euro currency [date accessed 13.11.2025]

[20] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type, By End-Use Industry, and Regional Forecast, 2025-2032. Available at: UV Stabilizers Market Size & Share | Global Report [2032]

[21] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type, By End-Use Industry, and Regional Forecast, 2025-2032. Available at: UV Stabilizers Market Size & Share | Global Report [2032]

[22] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: c68f587b-0df4-1972-c181-4358ca305934 (europa.eu) ; ECHA CHEM – ECHA Chemicals Database. Available at: ECHA CHEM [date accessed 05.09.2025]

[23] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: c68f587b-0df4-1972-c181-4358ca305934 (europa.eu) ; ECHA CHEM – ECHA Chemicals Database. Available at: ECHA CHEM [date accessed 05.09.2025]

- 2-(2H-Benzo[d][1,2,3]triazol-2-yl)-6-(2-phenylpropan-2-yl)-4-(2,4,4-trimethylpentan-2-yl)phenol (UV-928) and
- 2-(2H-benzotriazol-2-yl)-4-methylphenol (UV-P).

It indicated that the best course of regulatory action was to prepare an Annex XV dossier under the REACH Regulation (SVHC, substance of very high concern) for UV-326, UV-234 and UV-329, and to prepare an Annex VI dossier under Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation)[24] for UV-P (proposed classification - Aquatic Chronic 1, H410, M=10 and Skin Sens. 1, H317 (may cause an allergic skin reaction)).[25]

In December 2023, UV-326 and UV-329 were added as substances of very high concern in the Candidate List for eventual inclusion in Annex XIV based on their vPvB (very persistent, very bioaccumulative) properties.[26] In 2023, a Delegated Regulation amending the CLP Regulation set out new hazard classes, including for vPvB and PBT (persistent, toxic and bioaccumulative) substances.[27] In June 2025, the UV-P proposed classifications were adopted.[28] Table 1-1 summarises the current agreed harmonised classifications for each substance.

In 2024, the European Chemicals Agency (ECHA) published an Assessment of Regulatory Needs (ARN) for hydroxyphenyl benzotriazoles, including UV-326, UV-329, UV-234 and UV-P. It indicated a range of proposed regulatory actions, with compliance checks (CCH) suggested as a first step, and restriction under REACH as a potential last regulatory action. The justification provided in the published ARN noted that releases from the environment occur from consumer and widespread professional uses, that are often non-contained and cannot be avoided.[29]

Table 1-1: Summary of agreed harmonised classifications under Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP Regulation).[30]

| Substance | Human health classifications | Environmental classifications |
|---|---|---|
| UV-326 | No harmonised classifications | |
| UV-329 | No harmonised classifications | |
| UV-234 | No harmonised classifications | |
| UV-P | Skin Sens. 1B, H317 | Aquatic Chronic 1, H410, M-factor=10 |

In this context, the European Light Stabilisers and Antioxidants Association (ELiSANA) has commissioned Ricardo to independently assess the baseline emissions to the environment during the manufacture of products that contain UV-326, UV-329, UV-234 and/or UV-P, and to determine the influence of current and future risk management measures on these emissions. The following sub-sections set out the aims and scope of the assessment, as well as the structure of the report.

### 1.2.1 Environmental releases

The ECHA ARN report outlines that UV-light stabilisers are potentially emitted to the environment via the production of plastic articles at industrial sites, the finishing of plastic articles by professionals, as well as the

[24] European Commission (2008). Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation). Available at: CLP Legislation - ECHA

[25] European Chemicals Agency (2022). Regulatory Management Option Analysis Conclusion Document for UV-329, UV-326, UV-234, UV-P, UV-928. Available at: RMOA_Conclusion_Doc_v2_20141010.docx

[26] European Chemicals Agency (2023). Inclusion of substances of very high concern in the Candidate List for eventual inclusion in Annex XIV. Available at: 05ea7d09-6615-9ac3-be76-5c9cd96b8eb7

[27] European Chemicals Agency (2023). New hazard classes 2023. Available at: New hazard classes 2023 - ECHA

[28] European Chemicals Agency. Registry of CLH intentions until outcome – UV-P. Available at: Registry of CLH intentions until outcome - ECHA

[29] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: 309919c8-feff-284a-bea3-0ed65a61e7de

[30] European Chemicals Agency. ECHA CHEM – ECHA Chemicals Database. Available at: ECHA CHEM [date accessed 05.09.2025]

indoor and outdoor use of rubber/ plastic articles, by both professionals and consumers, and during article service life.[31]

According to the ARN document releases to the environment cannot be controlled for washing and cleaning products (consumer, professional), cosmetics and personal care products (consumer, professional), perfumes and fragrances (consumer only), adhesives and sealants (consumer, professional), coatings and paints (consumer, professional), and inks and toners (professional only).[32] These use patterns can lead to higher emissions of UV-light stabilisers because products can be subject to frequent handling, less controlled use patterns, and washing/ cleaning (e.g., down the drain releases). This often results in higher and more diffuse emissions of UV-light stabilisers over the service life of the product.[33]

The extent to which UV-light stabilisers are emitted to the environment depends on several factors, such as environmental behaviour (e.g., biodegradation rate, adsorption potential, volatility), the end use of the product (e.g., indoor or outdoor use, consumers and/or professional use, wide dispersive use), and whether the stabiliser is bound into the polymer matrix or freely available in a final product.[34] When stabilisers are bound into a polymer matrix, they are embedded within the material and, depending on the exact properties of the substance and matrix, can diffuse slowly through the polymer matrix before release.[35] Conversely, UV stabilisers that are not bound into a solid matrix, such as in cosmetic products, cleaning sprays or liquid formulations (e.g., coatings) are freely available at the surface and can lead to comparatively higher volumes of releases to the environment.[36] During article service life, emissions of UV-light stabilisers are expected to be lower when they are chemically bound to a polymer, with emissions primarily driven by the physical breakdown of the host material.[37]

## 1.3 AIMS

ELiSANA aims to use this Study as evidentiary support in their future engagement with European Public Authorities in light of potential regulatory action on UV-light stabilisers, including a potential restriction on the placing on the market and use in the European Union (EU).

The specific objectives of the Study include:

- To gather secondary and primary evidence of the industrial and professional uses of selected UV-light stabilisers across 10 key sectors in the EU-27, to facilitate a full use mapping.
- To produce an estimate of baseline emissions of each UV-light stabiliser at the sectoral level, that arise as a result of the manufacture of products that contain UV-light stabilisers.
- To identify the risk management measures currently applied during the manufacture of masterbatches/products containing UV-light stabilisers and that contribute to mitigating environmental emissions.
- To identify potential new risk management measures that could be employed to further reduce emissions to the environment.
- To summarise the key findings.

In summary, this Study will aim to quantify, to the extent that is possible, the baseline emissions for each sector in scope, and the associated emissions reduction that may be achievable following the potential implementation of additional risk management measures.

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[31] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: 309919c8-feff-284a-bea3-0ed65a61e7de

[32] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: 309919c8-feff-284a-bea3-0ed65a61e7de

[33] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[34] Pawlowski *et al,* (2025). Cosmetic UV filters used in sunscreens and their impact on corals put into perspective, *Environmental Sciences Europe*, 37, 173. Available at: https://doi.org/10.1186/s12302-025-01242-2

[35] Chen *et al.* (2024). Benzotriazole ultraviolet stabilizers in the environment: A review of occurrence, partitioning and transformation, *Science of the Total Environment*, 954, 176362. Available at: https://doi.org/10.1016/j.scitotenv.2024.176362

[36] Chen *et al.* (2024). Benzotriazole ultraviolet stabilizers in the environment: A review of occurrence, partitioning and transformation, *Science of the Total Environment*, 954, 176362. Available at: https://doi.org/10.1016/j.scitotenv.2024.176362

[37] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

## 1.4 SCOPE

The Study scoping dimensions are defined below, comprising substance scope, sectoral scope, and geographical scope. The Study focused on identifying the professional and industrial uses of the UV-light stabilisers in scope (see below) in the manufacture of products under each sector. It is worth noting that this Study has not assessed emissions associated with the manufacture of the UV-light stabilisers, or consumer uses of individual products.

### 1.4.1 Geographical and temporal scope

The geographical scope of this Study relates to the uses and emissions of the four UV-light stabilisers in the EU-27.

### 1.4.2 Chemical and sectoral scope

This Study investigated the uses and emissions of the following substances across the following sectors (Table 1-2). It is of relevance to the analysis conducted in this Study to note that these substances exhibit low volatility properties.

Table 1-2: Substance and sectoral scope for this Study.

| Substance | CAS | EC | Sectoral scope |
|---|---|---|---|
| **UV-329** – 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3- tetramethylbutyl)phenol | 3147-75-9 | 221-573-5 | 1. Renewable energy<br>2. Building and construction<br>3. Electronics<br>4. Coatings, paints and inks<br>5. Adhesives and sealants<br>6. Mobility and automotive<br>7. Textiles and fibres<br>8. Wire and cable<br>9. Packaging<br>10. Sports equipment |
| **UV-326** – 2-(2'-hydroxy -3' -tert-butyl-5'-methylphenyl)-5-chloro benzotriazole | 3896-11-5 | 223-445-4 | |
| **UV-234** – 2-(2H-benzotriazol-2-yl)-4,6-bis(2- phenyl-2- propanyl)phenol | 70321-86-7 | 274-570-6 | |
| **UV-P** – 2-(2H-benzotriazol-2-yl)-4-methylphenol | 2440-22-4 | 219-470-5 | |

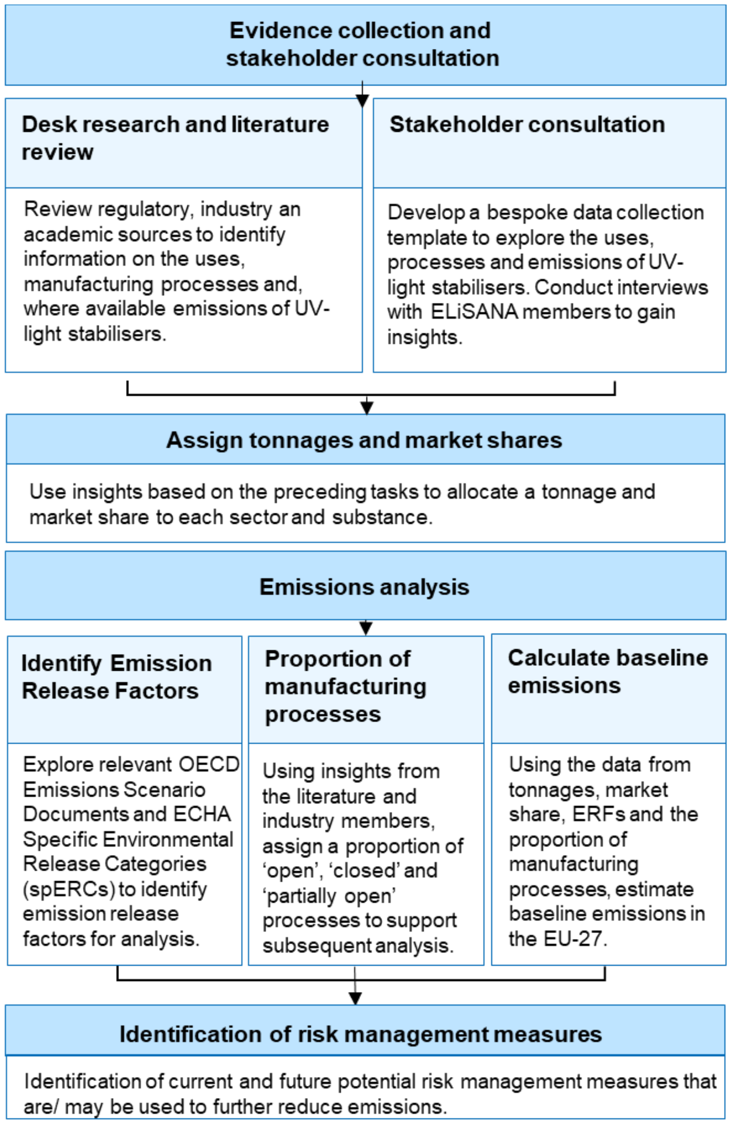
## 1.5 METHODOLOGY AND LIMITATIONS

This Section presents an overview of the methodology and its limitations, with further detail provided in Appendix 1.

### 1.5.1 Overview of the methodology

A multi-step approach has been employed to determine the uses, emissions and potential risk management measures of UV-light stabilisers. This is summarised in Figure 1-1, with a detailed description of the methodology summarised in Appendix 1.

Figure 1-1: Overview of the methodology.




### 1.5.2 Assumptions and limitations

- The sectoral scope of this project does not cover all known uses in the EU-27 and therefore any conclusions drawn may not be applied to the EU overall.
- This project examines emissions from the manufacture of products containing UV-light stabilisers, and excludes emissions from the manufacture of UV-light stabilisers, and emissions from consumer uses. As such, the emissions estimates calculated do not represent all uses and emissions at the EU-27 level.
- The methods applied draw on publicly available data, for example REACH tonnage band data, published Emission Release Factors (ERFs, that assume no risk management measures are implemented), as well as using a preliminary assessment of the proportion of closed, open and partially open manufacturing processes. This Study is therefore not able to conclude on the estimated UV-light stabilisers emissions to the EU-27 overall, and instead the results from indicative scenarios are presented. Additionally, the analysis of emission represents a worst-case scenario, with the true picture expected to be more nuanced.
- The market share (i.e., volume of each substance predicted to be used in each sector) is based on some industry insights and has been iterated using several sources of data. The data ranges used are

broad, to protect confidential business information, which leads to a greater degree of uncertainty and reduced nuance in calculated emissions between sectors and substances.

- Due to the methods used to calculate emissions, variation in emission volumes is small and derives only from differences in market share allocations, and any differences determined between manufacturing processes.

## 1.6 ORGANISATION OF THE REPORT

- Section 2 'Baseline – uses and emissions' outlines the identified uses and manufacturing processes for the relevant sectors in scope of this Study. It includes a summary of the scenario-based emissions analysis taken forward for assessment, as well as the assignment of tonnages allocated to each sector (i.e., market share). Finally, it includes the results of the environmental emissions analysis (including any risk management measures assumed to be in place).
- Section 3 'Potential risk management measures and emissions reduction' outlines the additional measures that may be used in future to further reduce emissions, including a consideration of their efficiencies.
- Section 4 – 'Conclusions' summarises the findings of the report.
- Appendices:
    - Appendix 1 – Methodology (including all methods and data input values)
    - Appendix 2 – Identified uses and substance mapping
    - Appendix 3 – Detailed emissions estimates
    - Appendix 5 – Physico-chemical properties of UV-light stabilisers

# 2. BASELINE – USES AND EMISSIONS

## 2.1 USE MAPPING

As highlighted in Section 1.1, UV-light stabilisers are used in an array of sectors and end uses to protect products from the effects of UV radiation. In this Study, uses were identified through several methods, including the review of publicly available REACH registration information, desk-based research and stakeholder consultation. REACH registration information is presented separately as the use of Product Category (PC) codes do not align with the sectors in scope of this Study. The following sections focus on the use categories identified through REACH registration databases, followed by an in-depth review of the uses identified relevant to the sectors in scope. Under REACH, registrants must describe all identified uses of a substance throughout its lifecycle, including formulation (F), industrial use (I), professional use (P), consumer use (C) and article service life (A).[38] The ECHA website includes the use map for Plastic Additives, which sets out information on the uses and conditions of use (e.g., environmental, worker exposure) across the plastics value chain.[39] Table 2-1 below outlines the relevant Product Category codes identified via the review of REACH registration information for each substance in scope, with a summary of the relevant lifecycle stage for each substance and PC. The information available from REACH registration data does not directly correspond to the sectors covered in this Study. Many relevant applications for this Study will be captured by PC 32 'Polymer preparations and compounds'.

Table 2-1: Overview of uses of the substances in scope, taken from publicly available REACH registration information.[40]

| Product category | UV-329 | UV-326 | UV-234 | UV-P |
|---|---|---|---|---|
| **PC 1: Adhesives, sealants** | **F, I, P, C** | **F, I, P, C, A** | **I, P, C** | **F, I, P, C, A** |
| PC 3: Air care products | C | C | | |
| PC 4: Anti-freeze and de-icing products | C | | | |
| PC 8: Biocidal products (e.g. disinfectants, pest control) | C | C | | |
| **PC 9a: Coatings and paints, thinners, paint removes** | **F, I, P, C** | **F, I, P, C, A** | **F, I, P, C** | **F, I, P, C, A** |
| PC 9b: Fillers, putties, plasters, modelling clay | I, C | C | | |
| PC 9c: Finger paint | C | | | |
| PC 14: Metal surface treatment products | | C | A | |
| PC 15: Non-metal surface treatment products | C | C | | |
| PC 17: Hydraulic fluids | | F | | |
| **PC 18: Ink and toners** | **F, I, P, C** | **F, I, P, C** | **I, P, C** | **F, I, P, C** |
| PC 19: Intermediate | I | I | | I |
| PC 21: Laboratory chemicals | | F, I | | |

[38] European Chemicals Agency (2015). Guidance on Information Requirements and Chemical Safety Assessment. Chapter R.12: Use description. Available at: https://echa.europa.eu/documents/10162/13632/information_requirements_r12_en.pdf/ea8fa5a6-6ba1-47f4-9e47-c7216e180197

[39] European Chemicals Agency. Use maps. Available at: Use maps - ECHA

[40] ECHA (2024). Assessment of Regulatory Needs - Hydroxyphenyl Benzotriazoles. Available: c68f587b-0df4-1972-c181-4358ca305934 (europa.eu) ; ECHA CHEM – ECHA Chemicals Database. Available at: ECHA CHEM [date accessed 05.09.2025]

| Product category | UV-329 | UV-326 | UV-234 | UV-P |
|---|---|---|---|---|
| PC 23: Leather treatment products | | | | |
| PC 24: Lubricants, greases, release products | C | | | |
| PC 25: Metal working fluids | | F | | |
| PC 26: Paper and board treatment products | I | I | | I |
| PC 27: Plant protection products | | P | | |
| PC 28: Perfumes, fragrances | F, C | F, C | | |
| PC 30: Photochemicals | | I, C | | |
| PC 31: Polishes and wax blends | C | C | | |
| **PC 32: Polymer preparations and compounds** | **F, I, P, A** | **F, I, P, C, A** | **F, I, P, C, A** | **F, I, P, C, A** |
| **PC 34: Textile dyes, and impregnating products** | **C** | **F, I, P, C, A** | | |
| PC 35: Washing and cleaning products | F, C | I, P, C | | |
| PC 39: Cosmetics, personal care products | C | C | | |

Key: F: formulation, I: industrial use, P: professional use, C: consumer use, A: article service life

### 2.1.1 Sectoral uses

In addition to the REACH registration information presented above, literature searches and stakeholder engagement exercises were conducted to identify the specific uses of the UV-light stabilisers relevant to the sectors in scope. Across all sectors, the primary identified function of the UV-light stabilisers was to prevent or delay degradation caused by exposure to UV radiation, so that the visual and mechanical properties of each product are maintained.[41] Table 2-2 presents a high-level summary of the identified uses at the substance and sector level.

Table 2-2: Summary of identified uses at the substance and sector level.

| Sector | UV-326 | UV-329 | UV-234 | UV-P |
|---|---|---|---|---|
| **Adhesives and sealants** | x | x | x | x |
| **Building and construction** | x | x | x | x |
| **Coatings, paints and inks** | x | x | x | x |
| **Electronics** | x | x | x | x |
| **Mobility and automotive** | x | x | x | X |
| **Packaging** | x | x | x | x |
| **Renewable energy** | | | x | |
| **Sports equipment** | x | | x | |
| **Textiles and fibres** | x | | x | x |
| **Wire and cable** | x | x | x | |

[41] WellTChem (2024). The Ultimate Guide to UV-Light Stabilisers 2024. Available at: [The Ultimate Guide to Light Stabilizers 2024 - Wellt]()

The following sub-headings present a summary of the uses identified for each sector. Appendix 2 contains the full outputs of this exercise, with a summary of all uses identified per sector, and a mapping of which UV-light stabilisers were identified for use in each sector. To note, discussion around the presence or absence of a specific substance at the sectoral level is based on literature validated uses only. Similarly, where a substance has been flagged as 'not being used' in a particular sector, it is recognised that this may be attributable to a methodological limitation of this Study (i.e., relying on literature data).

#### *2.1.1.1 Adhesives and sealants*

The main identified uses for the 'adhesives and sealants' sector were hot-melt adhesives and pressure sensitive adhesives, as well as several references to the use of UV-light stabilisers in 'generic adhesives and sealants'. Uses in this sector were identified for all four UV-light stabilisers (UV-P was only identified through publicly available REACH registration information).

Hot-melt adhesives are typically heated to form a liquid and solidify at room temperature to form a set polymer. They are used for products such as packaging, bookbinding and textile repairs. Pressure-sensitive adhesives are typically applied to a continuous substrate. They are soft and tacky and readily adhere to surfaces, remaining soft and tacky when in use. Examples include tapes (e.g., duct, masking) and self-adhesive labels.[42]

#### *2.1.1.2 Building and construction*

The building and construction sector was identified as a significant user of all four substances in scope of this assessment, though insights from industry experts indicate that UV-329 may be the most widely used in this sector. UV-light stabilisers are used extensively in the building and construction industry in indoor and outdoor applications. UV-light stabilisers are particularly crucial in outdoor applications to protect materials such as roofing membranes, exterior cladding, window and door profiles, decking, fencing, and pipes from degradation caused by prolonged exposure to sunlight. In the absence of UV-light stabilisers, the discoloration and degradation of these products would likely be accelerated.[43] They are also used in applications like laminated safety glass.

For indoor applications, UV-light stabilisers are used in products such as flooring, wall panels, and furniture components (e.g., edgebanding, panels). Indoor exposure to UV radiation is expected to be lower compared to outdoor applications, however UV-light stabilisers are used to preserve properties such as colour, gloss, and flexibility.

#### *2.1.1.3 Coatings, paints and inks*

As with building and construction applications, UV-light stabilisers are used extensively in both indoor and outdoor applications in the coatings, paints and inks sector(s). Much of the information obtained through publicly available sources and the stakeholder consultation exercise pertained to the use of UV-light stabilisers in the coatings sector. Fewer uses were identified in the paints and inks sector, though the uses presented in this report are non-exhaustive. UV-234 and UV-326 appear to be the most frequently used additives identified through this assessment and UV-329 appears to be used to a lesser extent. UV-P was only identified through publicly available REACH information.

UV-light stabilisers are used in coatings for differing purposes, for example in wood coatings, coatings for wind turbines or other external surfaces (protective coatings), in vehicle coatings or window blinds (decorative coatings), or specific high-performance coatings. In all instances, the UV-light stabilisers are used to enhance the durability and longevity of the lifespan of the coating.

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[42] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

[43] Synesqo (2025). How UV Stabilizers and Antioxidants Advance Construction Applications. Available at: Polymer Additives for Construction Applications | Syensqo

#### 2.1.1.4 Electronics

All substances were identified for their use in electronics applications, with UV-234 and UV-326 being the most frequently identified. UV-light stabilisers are used in a wide array of applications in the electronics sector. The most commonly identified use in this sector was 'housings', which are surrounds used to protect sensitive electrical components from environmental exposures.[44] The Study identified that all four substances are used in housings for a range of end applications, such as consumer electronics, power tools, generic components, wires and cables, and small appliances.

Several uses were identified related to photovoltaics, such as electrical components, frames, wire and cables and elastomers for jackets. They are also used in lighting and electrical components.

#### 2.1.1.5 Mobility and automotive

The mobility and automotives sector was identified as a significant user of UV-329 and UV-234, and was allocated a higher market share for these substances for the emissions analysis (see Section 2.3.3), though uses of all four substances were regularly identified. Based on research insights, this sector appears to be one of the largest end markets for UV-light stabilisers.

These substances are used for both external applications (housings, frames, bumpers, headlamp lenses, lamps, blinkers, mirror housings, trims, covers, flaps, lids and panels) and internal applications (dashboards, door trims, instrument panels, sun visors and compartments). Additionally, they are also used in glazing materials, highlighting their versatility and importance throughout the entire vehicle.

#### 2.1.1.6 Packaging

The packaging sector was identified as one of the biggest markets of UV-light stabilisers in the EU (all stabilisers, broad applications, see Section 2.3.3 for further justification). However, the research conducted in this report indicates that they may be a comparatively smaller use for these specific substances. Nevertheless, all four substances were identified for their use in this sector.

They are used in a range of packaging types, from heavy duty packaging and solid crates to flexible and thin film packaging. Additionally, the versatility of use of these substances is demonstrated by their use in printing materials, bottles and bottle caps, as well as in coffee cups and sports bottles. In summary, they are used in a range of both flexible and rigid applications, for heavy duty and light weight packaging.

#### 2.1.1.7 Renewable energy

Instances of use of UV-light stabilisers were harder to validate in this Study. The literature reviewed indicates that UV-light stabilisers (no specific substances identified) may be used in organic solar cells, however it was not possible to validate the exact substance or place of use beyond academic applications.[45] UV-234 was additionally identified as being used in coatings for the rotor component of wind turbine.

#### 2.1.1.8 Sports equipment

UV-234 and UV-326 were identified for their use in sports equipment in helmets, paddles and playground equipment (UV-234) and in artificial turf (UV-326).

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[44] Yongu. How Do Electronic Housings Protect Components? Available at: [1 new message](1 new message)

[45] Zhang *et al.,* (2025). Enhancing UV Stability and Charge Extraction in Organic Solar Cells with Phenyl-Linked Aromatic Self-Assembled Monolayer, *Advanced Functional Materials*, 35, 2423178. Available at: https://doi.org/10.1002/adfm.202423178

### 2.1.1.9 *Textiles and fibres*

Several generic uses of UV-light stabilisers were identified for the textiles and fibres sector for UV-234, UV-326 and UV-P. No instances of use of UV-329 were identified. Uses were identified for fibres for automotive, building and construction and carpet and upholstery applications (exact uses were not specified, all for UV-234). UV-326 was identified in clothing uses including PVC shoes, soles and leather, as well as textile dyes. UV-P was identified for its use in polyester and spandex fibres.

### 2.1.1.10 *Wire and cable*

Finally, UV-326, UV-329 and UV-234 were identified for uses in the wire and cable sector (with some overlaps noted between the electronics sector, though these overlaps were disaggregated as part of the data processing activities). The main uses identified (for all three substances) were cables of various types, including outdoor cables and charging cables, as well as their use in 'wires' (no further details specified).

## 2.2 MANUFACTURING PROCESSES AND POTENTIAL EMISSION RELEASES

The uses identified in this Study primarily relate to the incorporation of UV additives into polymers for uses in plastic end products, except for the adhesives and sealants and coatings, paints and inks sectors. This Section outlines the most frequently used processes to manufacture the products identified throughout this Study, and where emissions may occur. Processes for plastics manufacture and emissions are outlined separately to those for adhesives and coatings.

The plastics value chain is comprised of several stages. Raw materials for plastics are typically fossil-fuel based (e.g., crude oil, natural gas) and are extracted and processed before they are turned into plastic via polymerisation reactions.[46] A masterbatch is typically a solid, concentrated mixture of pigments and/or additives that is used to impart additional properties into the polymer.[47] Masterbatches are encapsulated into carrier resins and are added to raw polymers during the manufacturing process. This process facilitates the manufacture of plastics customised to different colours and with different properties.[48] Masterbatches are then converted into finished articles via different manufacturing processes, which are outlined in Section 2.2.2.

Emissions that arise during the manufacture of plastics (not specific to UV-light stabilisers) may occur at different stages of the process, including during raw material extraction, the production of the base plastic, the production of masterbatches, and/or during the production of finished articles. This Study focuses on determining the emissions of four UV-light stabilisers during the manufacture of the products/uses identified and outlined in Section 2.1.1, i.e., following the masterbatch process. The remainder of this section outlines typical manufacturing processes for both the production of finished articles and the production of masterbatches, including an assessment of where emissions may occur.

### 2.2.1 Production of masterbatches

As outlined above, the use of masterbatches during plastic manufacturing offers specific benefits such as the uniform distribution of pigments and additives. Masterbatches optimise the use of raw materials and require relatively small volumes and allow for the properties of the end polymer to be precisely controlled, which leads to both processing and financial efficiencies.[49]

Masterbatch manufacturing comprises several steps: raw material selection and pre-mixing; compounding and extrusion; cooling and pelletisation; quality control and testing.

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[46] TraceX Technologies (2023). Understanding the plastic value chain. Available at: Understanding Plastic Value Chain | Sustainability in Plastics

[47] Abbey Masterbatch. Masterbatch: What It Is, How It Works, and Its Benefits. Available at: Masterbatch: What It Is, How It Works, and Its Benefits | Abbey Masterbatch

[48] Abbey Masterbatch. Masterbatch: What It Is, How It Works, and Its Benefits. Available at: Masterbatch: What It Is, How It Works, and Its Benefits | Abbey Masterbatch

[49] Suryamb Blog (2025). Masterbatch Manufacturing Process: A Step-by-Step Overview. Available at: Masterbatch Manufacturing Process: A Step-by-Step Overview - suryamb Blog

In the first instance, the base resin, pigments and additives are chosen for the required final properties. Compounding refers to the process by which additives are incorporated into the base polymer. Various closed or partially-open processes can be used to perform the compounding process, with the use of extruders being the most common.[50]

A pre-mixing step can be carried out to ensure the raw material is input to the extruder as a homogenised mixture, though this is not always necessary.[51] The raw materials (e.g., polymer, additives, pigments) are loaded into a hopper which allows for the materials to be fed into the extruder at a constant rate. Once in the extruder, the raw materials are heated to the polymer melt temperature. Screws in the extruder facilitate mixing of the raw materials and feed it through the machine, which results in a polymer blend with the additives incorporated into the matrix.[52,53,54]

This process can be used to produce batches with high concentrations of additives for further dilution later ("masterbatch"), or batches with additive concentrations intended for the finished article ("compound").

According to the OECD Emissions Scenario Document on Plastic Additives, volatile emissions may be produced during the extrusion process, particularly as a result of heating the raw materials to elevated temperatures, and they are vented and filtered from the extruder.[55] The nature of emissions can be influenced by various factors including, but not limited to, the resin type, the type of additive, the processing temperature and/or oxygen content, and the operating conditions.[56] According to stakeholders, masterbatches that are filled with powders result in increased emissions to air when compared to liquid masterbatches. However, pellets are the most handled form of masterbatch, and thus emissions to air from this process are reported to be low.

### 2.2.2 Production of finished articles

The process(es) of transforming masterbatches and compounds into finished articles is referred to as 'converting'. Following the identification of specific finished articles for each substance and each sector in scope, information on individual manufacturing processes was sought through additional literature searches and consultation with stakeholders/ ELiSANA members. Several key manufacturing processes were identified that are relevant for many of the uses in scope of this Study. These are outlined below, including a summary of the overall process and potential areas for emissions. To note, this is not a comprehensive list of all manufacturing processes.

The specific process selected for converting depends on the nature of the plastic and the final article.[57] For example, thermoplastics are melted (often using the extrusion process), formed into a new shape and then cooled. Thermoplastics are typically recyclable and can be reshaped for subsequent uses. Conversely, thermosetting resins are cured using heat and pressure and are not recyclable.[58,59]

Emissions that occur during these manufacturing processes are typically process dependent, and primarily influenced by whether the process is closed, open or partially open. Table 2-3 summarises these different process types. Emissions differ between these processes because the extent to which they are contained directly impacts how much material – in this case, additives – can be released into the surrounding environment. In closed processes, emissions are limited as the equipment is fully sealed. Conversely, open processes expose materials directly to the air, and thus emissions may arise due to volatilisation, dust formation and/or handling losses. Partially open processes incorporate aspects of both open and closed processes. For example, some degree of containment is used, such as ventilation or intermittent closing, but emissions may still arise during mixing or transfer. As such, closed processes typically result in the lowest

[50] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[51] EuPC and EuMBC. Use maps for masterbatching, compounding, and converting processes. Available at: Use maps - ECHA

[52] EuPC and EuMBC. Use maps for masterbatching, compounding, and converting processes. Available at: Use maps - ECHA

[53] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[54] Nanjing Jieya (2024). Understanding the twin screw extruder diagram: Extrusion Technology Demystified. Available at: Understanding the twin screw extruder diagram: Extrusion Technology Demystified - Jieya

[55] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[56] Borealis Group (2022). Statement on impurities. Available at: Emission-EN-ed.06.pdf

[57] EuPC and EuMBC. Use maps for masterbatching, compounding, and converting processes. Available at: Use maps - ECHA

[58] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[59] Silverstar Chemical (2025). Recycling revolution: Thermoplastics vs Thermosets. Available at: Recycling Revolution: Thermoplastics vs Thermosets

volume of emissions, with open processes leading to higher volumes, and partially open processes leading to a middle ground of emissions, though this is process dependent and may be an oversimplification.[60]

Table 2-3: Summary of manufacturing process types.[61]

| Process type | Description | Example processes |
|---|---|---|
| **Closed** | The material flow is largely contained (no, or minimal, exposure to ambient environment). The process operations take place within sealed or vented enclosures. | Extrusion, injection moulding, compression moulding, extrusion blow moulding, injection blow moulding |
| **Partially open** | Some exposure of the polymer/additive mixture to the environment during processing; part of the process is enclosed, but some steps (or surfaces) are exposed to ambient conditions under operating or near-operating conditions. | Film extrusion, paper and textile coating |
| **Open** | The polymer or mixture is exposed to ambient or near-ambient environment throughout at least part of processing. There is minimal enclosure, so mass transfer (vapour, particulates) to ambient is easier. | Thermoforming, calendering, fibre-reinforced plastic fabrication |

#### *2.2.2.1 Extrusion*

Extrusion is an extension of the process outlined in Section 2.2.1 and is used to produce profiles, pipes, wire coatings and sheets. As outlined above, the compound or masterbatch is fed into the extruder where it is melted then is forced through a die to determine the final shape (e.g., flat sheets, cylindrical hollow pipes), before being cooled and solidified by a series of rollers.[62] Volatile emissions are likely to occur via the processes described in Section 2.2.1. Extrusion is typically a closed process, but can be classed as partially open when it used for film extrusion (film is cooled by travelling upwards over a vertical bubble).[63]

#### *2.2.2.2 Injection moulding*

Injection moulding is a closed process that involves the heating of the polymer blend (by extrusion) before the molten plastic is projected into a mould cavity. During the cooling process the plastic hardens, and the final article is produced.[64] Products containing two different materials or colours can be made using a two-shot injection moulding process. This process is used to produce a vast array of products, such as bottle caps, remote control casings and syringes.[65] One advantage of injection moulding is that it is a closed process that results in minimal emissions and produces minimal waste.[66]

#### *2.2.2.3 Blow moulding*

Blow moulding is a closed process that is used to manufacture hollow, lightweight products such as bottles and containers. Blow moulding involves heating plastic and forming a tube-like shape called a parison, and

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[60] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[61] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[62] Nanjing Jieye (2025). Sheet Extrusion: The Ultimate Guide to Process, Materials, and Applications. Available at: Sheet Extrusion: The Ultimate Guide to Process, Materials, and Applications - Jieya

[63] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[64] TWI. What is injection moulding? Definition, types and materials. Available at: What is Injection Moulding? – Definition, Types and Materials - TWI

[65] TWI. What is injection moulding? Definition, types and materials. Available at: What is Injection Moulding? – Definition, Types and Materials - TWI

[66] Plastic Supplies Dudley (2025). Understanding the Environmental Impact of Injection Moulding. Available at: Injection Moulding's Environmental Impact

emissions may occur at points where molten polymer or additives escape into the surrounding air.[67] There are three main types of blow moulding: extrusion, injection and injection stretch.[68]

In extrusion blow moulding, the parison is delivered to two halves of a mould by an extruder. The mould halves are then brought together around the hot extrudate to seal the top and bottom. The hollow products are created by blowing air through the parison. The article is cooled before releasing the moulds.[69]

Injection blow moulding differs to extrusion blow moulding as a preformed plastic shape is used instead of a parison. As with above, the plastic is injected into a mould and air is forced through the plastic to create a hollow shape.[70]

Finally, injection stretch blow moulding follows the same process as outlined above, but the plastic is stretched before the air is blown through it. This process is used to create more durable products, such as drinks bottles.[71]

#### *2.2.2.4 Calendering*

Calendering is an open process which is used to produce, amongst other things, standalone sheets with uniform dimensions.[72] The plastic blend is prepared prior to the calendering process, before being inserted into the calendering machine. In the calendering machine, the plastic is passed through a series of rollers, before passing through a high-pressure roller to reduce film thickness and increase density. The degree of calendering is controlled by speed, temperature and the inter-roll distance to modify the surface of the material. Depending on the desired product, the rollers may be heated or cooled.[73] During this process, volatile additives and particulates may be emitted.[74]

#### *2.2.2.5 Manufacturing processes for other sectors – adhesives and coatings*

*Coatings*

Many of the sectors and end uses in scope of this Study contain UV-light stabilisers that are incorporated into a solid plastic matrix and are manufactured using the processes outlined above. In addition, UV-light stabilisers have further applications, such as in coatings and adhesives. The manufacturing processes for these products are summarised below.

Coatings are typically produced in batch processes, whereby the individual constituents (including pigments and additives such as UV stabilisers) are mixed to produce a homogenous, stable blend of the finished product.[75] A traditional coatings manufacturing process comprises four key stages:

- Dispersion – all raw materials, including additives and powder pigments, are assembled to form a pigment concentrate.
- Milling – milling devices such as pebble mills, steel mills, horizontal bead mills, etc, are used to reduce the particle size of pigments and extenders.
- Finishing – any remaining liquid constituents are added and mixed with the milled raw materials.

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[67] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[68] Plastikcity (2024). What is blow moulding? A complete guide. Available at: What Is Blow Moulding? Process, Types, & Benefits Explained

[69] Plastikcity (2024). What is blow moulding? A complete guide. Available at: What Is Blow Moulding? Process, Types, & Benefits Explained

[70] Plastikcity (2024). What is blow moulding? A complete guide. Available at: What Is Blow Moulding? Process, Types, & Benefits Explained

[71] Plastikcity (2024). What is blow moulding? A complete guide. Available at: What Is Blow Moulding? Process, Types, & Benefits Explained

[72] Lead RP (2024). Calendering Process Basics: Knowing Its Principles and Application. Available at: Calendering Process Basics: Knowing Its Principles And Application - LEADRP - Rapid Prototyping And Manufacturing Service

[73] Lead RP (2024). Calendering Process Basics: Knowing Its Principles and Application. Available at: Calendering Process Basics: Knowing Its Principles And Application - LEADRP - Rapid Prototyping And Manufacturing Service

[74] OECD (2014). OECD Emission Scenario Document on Plastic Additives. Available at: Plastic Additives | OECD

[75] OECD (2009). OECD Emission Scenario Document on Coating Industry. Available at: Coating Industry (Paints, Lacquers and Varnishes) (EN)

- Filling – filtration and filling.[76]

*Adhesives*

The most frequently identified uses of UV-light stabilisers in the adhesives and sealants sector were hot melt adhesives and pressure sensitive adhesives. Hot melt adhesives are typically manufactured in a heated mixing/transfer process.[77] The individual constituents, including UV additives, are melted, extruded, poured and cooled to form a solid product, typically in an unsealed process. The final adhesive product may be formed (i.e., cooled) via dripping onto a cooling belt; injection moulding (sticks, blocks, cubes); extrusion (rods). Environmental releases may occur at the following stages:

- Residues from transport vessels
- Emissions to air from dust losses during transfer of solid/powdered components
- Volatile emissions during operations (air)
- Product sampling wastes to water, incineration or landfill; volatile emissions (air) during sampling.
- Equipment cleaning (water, incineration, landfill)
- Emissions to air (volatile chemicals) when loading molten adhesive to transport vessels
- Off-spec releases.[78]

Pressure sensitive adhesives (PSAs) can be organic solvent-based, or water based. Organic solvent-based adhesives are manufactured in a sealed process. The individual constituents are loaded into mixing equipment where they are combined using a high-speed dispenser programmed to specific settings. PSAs are typically applied to a tape or label substrate prior to distribution. Many of the above potential environmental releases are relevant for pressure sensitive adhesives. Specific environmental releases may occur at the following stages:

- Residues from transport vessels
- Emissions of volatile chemicals during cleaning
- Emissions from loading/unloading activities
- Mixing operations
- Sampling
- Equipment cleaning.[79]

Conversely, water-based pressure sensitive adhesives are typically formulated in unsealed processes, whereby the above described process takes place in open tanks. These adhesives typically contain low volatility solvents with stable additional components. According to the OECD Emissions Scenario Document on Adhesives, potential emissions sources are considered to be the same as for organic solvent-based adhesives, owing to the low volatility/high stability of the components.[80]

### 2.2.3 Summary

According to the OECD Emission Scenario Document on Plastic Additives, 55% of polymers are converted using closed processes. Injection moulding and blow moulding account for over half of the volumes converted at 37% and 20%, respectively. Table 2-4 contains a non-exhaustive summary of uses identified in this Study and their associated manufacturing process.

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[76] OECD (2009). OECD Emission Scenario Document on Coating Industry. Available at: Coating Industry (Paints, Lacquers and Varnishes) (EN)

[77] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

[78] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

[79] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

[80] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

Table 2-4: Summary of manufacturing processes used for applications in scope of this Study (non-exhaustive).

| Process | Relevant sectors | Example end products |
|---|---|---|
| Batch processes | Coatings, paints and inks<br>Textile fibres<br>Renewable energy | Generic coatings<br>Dyes |
| Sealed process | Adhesives and sealants | Pressure sensitive adhesives |
| Heated mixing/transfer | Adhesives and sealants | Hot melt adhesives |
| Extrusion | Building and construction<br>Electronics<br>Mobility and automotive<br>Packaging | Pipes<br>Decking and fencing<br>Film<br>Window and door profiles |
| Injection moulding | Mobility and automotive<br>Sports equipment<br>Packaging | Glazing<br>Sports helmets<br>Bottle caps |
| Injection blow moulding | Packaging | Bottles (generic, extensive uses) |
| Calendering | Wire and cable<br>Packaging<br>Textiles and fibres<br>Building and construction | Flexible PVC<br>Flexible packaging films<br>Flooring<br>Synthetic leather |

## 2.3 ALLOCATION OF SUBSTANCE TONNAGES AND SECTORAL MARKET SHARE

There is no single, publicly available source that provides EU tonnage information for the supply and use of UV-light stabilisers, disaggregated at the level of the substances and sectors in scope for this project. This section describes the process used to estimate the EU tonnage at the substance and sector level for each UV-light stabiliser in scope.

### 2.3.1 Data sources

During the literature review task, searches were conducted to identify publicly available information relating to a) volumes of UV-light stabilisers manufactured/imported into the EU and b) the market share (by volume or value) for UV-light stabilisers for the sectors in scope. Information on tonnages as supplied as part of substance registrations under Regulation (EC) No 1907/2006 of REACH was identified via the European Chemicals Agency Chemicals Database (ECHA CHEM).[81] According to ECHA CHEM, between 1,000 – 10,000 tonnes of each UV-light stabiliser in scope of this assessment are manufactured and imported into the EU per annum.[82]

To ascertain the market share of each sector, per substance (i.e., the proportion of each substance sold to/ used in each sector), confidential market information was obtained from ELiSANA members relating to their downstream customers. This information was complemented with additional sources, including several

[81] European Chemicals Agency. ECHA Chemicals Database. Available at: ECHA CHEM [accessed August 2025]

[82] Bumetrizole 100.021.315 | Overview - ECHA CHEM [date accessed 27.08.2025]; 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol 100.019.612 | Overview - ECHA CHEM [date accessed 27.08.2025]; 2-(2H-benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol 100.067.769 | Overview - ECHA CHEM [date accessed 27.08.2025]; 2-(2H-benzotriazol-2-yl)-p-cresol 100.017.700 | Overview - ECHA CHEM [date accessed 27.08.2025]

economics' reports, to determine an overall market share at the substance and sector level.[83,84,85,86] Please refer to Appendix A1.4 for a detailed methodological explanation of how the market share information was allocated.

### 2.3.2 Tonnage estimates per substance

Publicly available REACH data was used in this assessment, with each substance manufactured and imported between 1,000 – 10,000 tonnes per annum in the EU. In the absence of specific industry data, scenario-based analysis was conducted to model emissions at increments across the tonnage band: 1,000, 2,500, 5,000, 7,500 and 10,000. This scenario-based approach was used to provide granularity in the emissions analysis and capture potential emissions estimates across a range of scenarios, in the absence of specific tonnage volumes. The emissions analysis assumes that this is the tonnage of UV-light stabilisers consumed to produce the relevant products in scope and is not the final volume of the overall products manufactured.

### 2.3.3 Market share allocation per sector and per substance

Information from ELiSANA members, publicly available literature, economics' reports and insights from experts was triangulated to estimate the market share of each UV-light stabiliser, and for each sector. To protect confidential business information, a qualitative score was assigned to each sector as follows:

- Very low – corresponding to a market share of between 0-19%;
- Low – corresponding to a market share of between 20-39%;
- Medium – corresponding to a market share of between 40-59%;
- High – corresponding to a market share of between 60-79%;
- Very high – corresponding to a market share of between 80-100%.

Table 2-5 summarises the market share allocation per sector after all iterative steps were taken. For further information on the methodological steps taken to assign these allocations, please see Appendix A1.4.

Table 2-5: Estimated market share allocation (qualitative) per substance and per sector.

| Sector | UV-326 (tonnes) | UV-329 (tonnes) | UV-234 (tonnes) | UV-P (tonnes) |
|---|---|---|---|---|
| Adhesives and sealants | Very low | Very low | Very low | Very low |
| Building and construction | Low | Low | Low | Low |
| Coatings, paints and inks | Very low | Very low | Very low | Very low |
| Electronics | Very low | Very low | Very low | Very low |

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[83] Mordor Intelligence (2025). UV stabilisers market size and share analysis – growth trends and forecasts (2025-2030). Available at: [UV Stabilizers Market Size, Growth Drivers, Demand & Forecast 2030]

[84] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type (Hindered Amine Light Stabilizers (HALS), UV Absorbers, Quenchers, and Others), By End-Use Industry (Packaging, Automotive, Agriculture, Building & Construction, Adhesives & Sealants, and Others), and Regional Forecast, 2025-2032. Available at: [UV Stabilizers Market Size & Share | Global Report [2032]]

[85] Metatech Insights (2025). UV Stabilizers Market By Type (Hindered Amine Light Stabilizers, UV Absorbers, Quenchers, Blends Packages), By Application (Packaging, Automotive, Agriculture, Construction, Textiles & Fibres, Adhesives & Sealants, Personal Care Products, Others), By Polymer Type (Polypropylene, Polyethylene, Polyvinyl Chloride, Polyurethane, Others), By End-user (Packaging Industry, Building & Construction, Automotive & Transportation, Agriculture, Consumer Goods, Others), Global Market Size, Segmental analysis, Regional Overview, Company share analysis, Leading Company Profiles And Market Forecast, 2025 – 2035. Available at: [UV Stabilizers Market Share, Size, Trend & Growth 2025-2035]

[86] Stats & Research (2025). The Global UV Light Stabilizers Market is segmented By Type (Hindered Amine Light Stabilizers (HALS), UV Absorbers, Quenchers, and Others), By Application (Plastics, Coatings, Adhesives & Sealants and Others), By End-Use (Automobile, Construction, Building & Construction and Packaging), and By Region (North America, Europe, Asia-Pacific, South America, Middle East and Africa). Available at: [UV Light Stabilizers Market Size, Share And Forecasts 2032]

| Sector | UV-326 (tonnes) | UV-329 (tonnes) | UV-234 (tonnes) | UV-P (tonnes) |
|---|---|---|---|---|
| Mobility and automotive | Very low | Low | Low | Very low |
| Packaging | Very low | Very low | Very low | Very low |
| Renewable energy | Very low | Very low | Very low | Very low |
| Sports equipment | Very low | Very low | Very low | Very low |
| Textiles and fibres | Very low | Very low | Very low | Very low |
| Wire and cable | Very low | Very low | Very low | Very low |

The volumes of each substance used are not evenly distributed across all sectors. It is anticipated, however, that most sectors will be in the 'very low' or 'low' category based on the quantitative ranges assigned to these bands (0-19%, 20-39%) as there are 10 sectors in scope of this Study, and additional known sectors that have not been considered.

The economic reports on the UV-light stabilisers market (broader scope than the substances included in this report) repeatedly identified the automotive, building and construction, packaging, and agriculture sectors (not in scope), with some reports additionally highlighting adhesives and sealants and textiles and fibres as the main sectors of end use. The specific market allocations assigned to these sectors varied (e.g., one report attributed 41% of the market to mobility and automotive, whilst another attributed 22%), and the order of largest markets also varied (e.g., two stated mobility and automotive as the main sector, whilst two stated packaging).[87,88,89,90] This information was considered sufficiently representative of the UV-light stabilisers market to be applied to the sectors in scope, though additional sources were also considered before the final market share allocations were assigned. That is, the final allocation of market share data may not identically reflect the economic data from publicly available reports.

Through the review of ELiSANA members' data, publicly available literature, and insights gained from interviews with industry experts, a higher allocation (e.g., 'low') was assigned to the building and construction sector for all substances, and for the mobility and automotive sector for UV-329 and UV-234, as these were identified as the major uses. The remaining market allocations are more evenly distributed across the sectors in scope.

These market share allocations, combined with the scenario-based tonnage volumes in Section 2.3.2, were taken forward to determine the baseline emissions estimates presented in Section 2.4.

## 2.4 BASELINE EMISSIONS FROM THE MANUFACTURE OF PRODUCTS CONTAINING UV-LIGHT STABILISERS

This Section outlines the estimated baseline emissions of the UV-light stabilisers and sectors in scope in the EU-27. Please see Appendix 1 for a detailed methodological explanation and the assumptions taken forward

[87] Mordor Intelligence (2025). UV stabilisers market size and share analysis – growth trends and forecasts (2025-2030). Available at: UV Stabilizers Market Size, Growth Drivers, Demand & Forecast 2030

[88] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type (Hindered Amine Light Stabilizers (HALS), UV Absorbers, Quenchers, and Others), By End-Use Industry (Packaging, Automotive, Agriculture, Building & Construction, Adhesives & Sealants, and Others), and Regional Forecast, 2025-2032. Available at: UV Stabilizers Market Size & Share | Global Report [2032]

[89] Metatech Insights (2025). UV Stabilizers Market By Type (Hindered Amine Light Stabilizers, UV Absorbers, Quenchers, Blends Packages), By Application (Packaging, Automotive, Agriculture, Construction, Textiles & Fibres, Adhesives & Sealants, Personal Care Products, Others), By Polymer Type (Polypropylene, Polyethylene, Polyvinyl Chloride, Polyurethane, Others), By End-user (Packaging Industry, Building & Construction, Automotive & Transportation, Agriculture, Consumer Goods, Others), Global Market Size, Segmental analysis, Regional Overview, Company share analysis, Leading Company Profiles And Market Forecast, 2025 – 2035. Available at: UV Stabilizers Market Share, Size, Trend & Growth 2025-2035

[90] Stats & Research (2025). The Global UV Light Stabilizers Market is segmented By Type (Hindered Amine Light Stabilizers (HALS), UV Absorbers, Quenchers, and Others), By Application (Plastics, Coatings, Adhesives & Sealants and Others), By End-Use (Automobile, Construction, Building & Construction and Packaging), and By Region (North America, Europe, Asia-Pacific, South America, Middle East and Africa). Available at: UV Light Stabilizers Market Size, Share And Forecasts 2032

for the baseline estimation analysis. The emissions estimated in this report are expressed as total amounts emitted from the relevant industries. Subsequent treatment or dilution in surface water and partitioning to suspended matter or sediment has not been estimated and neither the potential emissions to soil due to the application of treated sludge to land for agricultural purposes. To note, due to the absence of a direct release into the terrestrial compartment default ERFs are not provided in the OECD Emission Scenario Document on Plastic Additives and thus emissions to soil are not calculated. The emissions reported herein can be considered a 'worst case scenario', as the ERFs do not take into account the use of risk management measures to abate emissions and the figures represent a percentage release which is tonnage dependent.

The annual emissions of the four UV-light stabilisers across the five tonnage scenarios were estimated for total releases to air (Table 2-6) and water (Table 2-7) across all sectors, at the EU-27 level. The central scenario for each tonnage band and substance is presented, with the lower and upper bound ranges presented in brackets to highlight the range of calculated emissions estimates. The results show broadly comparable orders of magnitude for all substances.

Total emissions increase proportionally with tonnage scenarios from 1,000 to 10,000 tonnes per year. The observed proportional increase in emissions across the different tonnage scenarios reflects the calculation methods based on OECD emission release factors (ERFs) or spERCs, where available. These factors represent fixed fractions of substance releases to specific environmental compartments per unit of material used. Consequently, when the input tonnage is scaled up, the resulting emissions increase linearly, as they are derived through direct multiplication of the tonnage by the corresponding release factors.

Overall, the calculated total releases across all manufacturing processes (including closed, semi-open, and open) span from approximately 0.09 tonnes per year to air and 0.5 tonnes to water at the 1,000-tonnage scenario to around 6 tonnes per year at the 10,000-tonnage scenario (1 tonne to air, 5 tonnes to water). As stated, the similarity in emission magnitudes across substances reflects the use of common environmental release factors for most sectors.

Table 2-6: Annual estimated 'worst-case' emissions of UV-light stabilisers to air for each substance and tonnage scenario, in tonnes per year.

| | Emissions of UV-light stabilisers to air (tonnes per year), for all sectors and tonnage scenarios at the EU-27 level | | | |
|---|---|---|---|---|
| **Tonnage scenario** | **UV-326** | **UV-329** | **UV-234** | **UV-P** |
| **1,000** | 0.098<br>[0.012 – 0.185] | 0.0906<br>[0.014 – 0.166] | 0.0991<br>[0.0140 – 0.184] | 0.0906<br>[0.012 – 0.169] |
| **2,500** | 0.150<br>[0.015 – 0.290] | 0.133<br>[0.021 – 0.245] | 0.157<br>[0.0217 – 0.293] | 0.144<br>[0.030 – 0.265] |
| **5,000** | 0.487<br>[0.061 – 0.923] | 0.453<br>[0.072 – 0.832] | 0.495<br>[0.0670 – 0.920] | 0.453<br>[0.061 – 0.844] |
| **7,500** | 0.732<br>[0.092 – 1.385] | 0.679<br>[0.109 – 1.248] | 0.743<br>[0.105 – 1.380] | 0.679<br>[0.091 – 1.267] |
| **10,000** | 0.976<br>[0.122 – 1.846] | 0.906<br>[0.145 – 1.663] | 0.991<br>[0.140 – 1.839] | 0.906<br>[0.121 – 1.689] |

Table 2-7: Annual estimated 'worst-case' emissions of UV-light stabilisers to water for each substance and tonnage scenario, in tonnes per year.

| | Emissions of UV-light stabilisers to water (tonnes per year), for all sectors and tonnage scenarios at the EU-27 level | | | |
|---|---|---|---|---|
| Tonnage scenario | UV-326 | UV-329 | UV-234 | UV-P |
| **1,000** | 0.540<br>[0.056 – 1.026] | 0.533<br>[0.059 – 1.001] | 0.541<br>[0.058 – 1.026] | 0.533<br>[0.056 – 1.012] |
| **2,500** | 1.351<br>[0.141 – 2.565] | 1.333<br>[0.147 – 2.519] | 1.355<br>[0.146 – 5.127] | 1.334<br>[0.141 – 2.526] |
| **5,000** | 2.702<br>[0.282 – 5.130] | 2.667<br>[0.293 – 5.039] | 2.710<br>[0.291 – 5.127] | 2.667<br>[0.282 – 5.051] |
| **7,500** | 4.053<br>[0.424 – 7.695] | 4.001<br>[0.441 – 7.558] | 4.065<br>[0.437 – 7.690] | 4.001<br>[0.423 – 5.577] |
| **10,000** | 5.404<br>[0.565 – 10.26] | 5.334<br>[0.588 – 10.078] | 5.419<br>[0.583 – 10.254] | 5.334<br>[0.564 – 10.103] |

Table 2-8 presents the emissions to air and water at the local level for the ten sectors in scope. Emissions estimates are expressed in kilograms (per day) instead of tonnes for ease of readability. The methods used to determine local level emissions are outlined in Appendix A1.6.2. To capture a range of data from all tonnage scenarios, the main value presented is the central estimate from the 5,000 tonnes scenario. The lower bound is lower estimate from the 1,000-tonnage band, and the upper bound is the upper scenario from the 10,000-tonnage band. The ERFs from the OECD ESD on plastic additives are the same for air and water, thus resulting in equal emissions for these sectors (all sectors except adhesives and coatings).

Presenting these results in this way therefore captures the entire range of potential emissions estimates in the EU, at the local level. It is worth noting, however, that these results reflect scenario-based analysis, and the exact volumes assigned to each sector are not known.

Sectoral and substance-specific distributions are derived from available emission factors, market shares, and the assigned degree of process containment (open vs closed systems, see Appendix 1). Any observed variations between substances and sectors largely reflect these factors. As noted above, the emissions estimates for the adhesives and sealants, and coatings, paints and inks sectors were based on spERC values based on formula type (adhesives and sealants: water- or solvent-based; coatings, paints and inks: water-, solvent- or powder-based) and were not dependent on whether the process was open or closed.

The largest estimated emissions were observed for the adhesives and sealants sector (0.006 kg/day to air and 0.036 kg/day to water, per substance) and the coatings, paints and inks sector (0.005 kg/day to air, 0.035 kg/day to water, per substance). These higher releases to water are driven by the input ERF values taken from spERCs, compared with the standard ERFs from the OECD ESD on Plastic Additives. There was no observed variation within these sectors at the substance level, as all substances were allocated the same market share (very low) and the default emissions release factors from the relevant spERCs were applied. Higher emissions may arise from these sectors compared to the solid plastic articles produced in other sectors due to the manufacturing processes used (Section 2.2.2), as the UV-stabilisers remain largely unbound in the liquid formulations.[91,92]

The identified emissions from the remaining sectors are of a similar magnitude, with very small variations between them. The lowest emissions were observed for the packaging (0.1 g per day (air and water)) and

[91] OECD (2009). OECD Emission Scenario Document on Coating Industry. Available at: Coating Industry (Paints, Lacquers and Varnishes) (EN)

[92] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

electronics (0.3 g per day (air and water)) sectors, with marginally higher emissions estimated for the building and construction, mobility and automotive, and textiles and fibres sectors.

Overall, however, the analysis suggests that no single substance dominates emissions, and that sectoral behaviour is the determining factor. Similarly, emissions to water are the primary driver of release, with volumes being approximately 6x higher for the adhesives and coating sectors compared to emissions to air. As discussed, the higher volumes of estimated emissions arise from the differences in input ERFs from the spERCs for adhesives and coatings.

Table 2-8: Emissions of UV-light stabilisers to air and water for all sectors, in grams per day (local level).

| | Aggregated emissions of UV-light stabilisers to air and water (grams per day), for all sectors | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **UV-326** | | **UV-329** | | **UV-234** | | **UV-P** | |
| | Air | Water | Air | Water | Air | Water | Air | Water |
| **Adhesives and sealants** | 6 [0.1 – 20] | 36 [0.7 – 140] | 6 [0.1 – 20] | 36 [0.7 – 140] | 6 [0.1 – 20] | 36 [0.7 – 140] | 6 [0.1 – 20] | 36 [0.7 – 140] |
| **Building and construction** | 0.6 [0.08 – 2] | 0.6 [0.08 – 2] | 0.5 [0.08 – 1] | 0.5 [0.08 – 1] | 0.4 [0.05 – 1] | 0.4 [0.05 – 1] | 0.7 [0.1 – 2] | 0.7 [0.1 – 2] |
| **Coatings, paints and inks** | 5 [0.09 – 17] | 35 [0.7 – 134] | 5 [0.09 – 17] | 35 [0.7 – 134] | 5 [0.09 – 17] | 35 [0.7 – 134] | 5 [0.09 – 17] | 35 [0.7 – 134] |
| **Electronics** | 0.3 [0.003 – 2] | 0.3 [0.003 – 2] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.2 [0.004 – 0.7] | 0.2 [0.004 – 0.7] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] |
| **Mobility and automotive** | 0.2 [0.005 – 0.9] | 0.2 [0.005 – 0.9] | 0.7 [0.1 – 2] | 0.7 [0.1 – 2] | 0.6 [0.08 – 1] | 0.6 [0.08 – 1] | 0.2 [0.003 – 0.6] | 0.2 [0.003 – 0.6] |
| **Packaging** | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.6] | 0.1 [0.003 – 0.6] |
| **Renewable energy** | 0 | 0 | 0 | 0 | 0.7 [0.01 – 3] | 0.7 [0.01 – 3] | 0 | 0 |
| **Textiles and fibres** | 0.7 [0.01 – 3] | 0.7 [0.01 – 3] | 0 | 0 | 0.4 [0.008 – 2] | 0.4 [0.008 – 2] | 0.5 [0.01 – 2] | 0.5 [0.01 – 2] |
| **Sports equipment** | 0.4 [0.008 – 2] | 0.4 [0.008 – 2] | 0 | 0 | 0.1 [0.003 – 0.5] | 0.1 [0.003 – 0.5] | 0 | 0 |
| **Wire and cable** | 0.3 [0.006 – 1] | 0.3 [0.006 – 1] | 0.3 [0.006 – 1] | 0.3 [0.006 – 1] | 0.3 [0.007 – 1] | 0.3 [0.007 – 1] | 0 | 0 |

Based on the methodological limitations of this Study (e.g., similar market share allocations, tonnage-based scenario analysis) it is not possible to draw conclusions on the exact volumes of UV-light stabilisers emitted in the EU-27 or at the local level. However, it is worth noting that the methods used in this assessment typically result in a conservative, worst-case estimate of emissions for the following reasons:

- In the absence of industry data, the tonnage allocations assume that 100% of the volume of UV-light stabilisers in each scenario is consumed for applications in scope of this Study. This is an overestimation, as there are known sectors that are not in scope of this assessment, and wider uses of these substances overall.
- OECD and spERC scenarios are designed to cover a wide range of industrial applications, and are therefore not tailored to specific site-level controls or mitigation measures. This means that in many real-world cases, actual emissions may be lower than predicted.
- Though the emission release factors in both documents are tailored to UV-light stabilisers (OECD) or non-volatile substances (spERCs), the analysis does not consider that, in practice, UV-light stabilisers are bound within polymer matrices during the masterbatch processes.[93] This decreases the likelihood of uncontrolled release during conversion processes, with environmental releases further reduced by enhanced encapsulation technologies.[94] If releases occur, these may most likely be in the polymer form and therefore disposed as solid waste.

## 2.5 RISK MANAGEMENT MEASURES

Risk management measures (RMMs), or engineering controls and techniques, are used in manufacturing processes to provide systemic, reliable and often cost-effective methods for reducing environmental emissions to chemical, physical and biological hazards. These measures typically also create process efficiencies that lead to costs savings, for example re-capturing expensive raw materials that can be re-used.[95] Some RMMs such as exhaust air ventilation with adequate air filtration, collection and incineration of sewage sludge typically provide 100% removal efficiencies.[96]

The hierarchy of controls identifies a preferred order of actions to take to best control workplace exposure and environmental releases. Engineering controls are third in the hierarchy, below elimination and substitution, and above administrative controls and use of personal protective equipment (PPE, relevant to human exposure).Elimination and substitution are preferred as they remove the hazard or reduce the risk, respectively, but engineering controls can be used to reduce or prevent emissions where elimination and substitution are not possible (or, can be used alongside these measures). Engineering controls are preferred over administrative controls as they are less prone to human error that may reduce their efficacy.[97]

The use of engineering controls additionally supports compliance with national and regional (EU-wide) legislation, such as Directive 2010/75/EU on industrial emissions (IED) and the revised Directive (EU) 2024/3019 concerning urban wastewater treatment.[98,99] Implementing controls helps to minimise uncontrolled releases. The rest of this Section outlines the most commonly identified risk management measures reported by companies during the stakeholder consultation period. These examples are based on a limited sample size and thus are not exhaustive.

The analysis in the preceding Section used default ERFs that do not take into account the use, and therefore efficiencies, of risk management measures. The results therefore present a worst-case scenario estimate of

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[93] Number Analytics (2025). Mastering UV Stabilisation in Polymers. Available at: Mastering UV Stabilization in Polymers

[94] Number Analytics (2025). Unlocking UV Stability in Polymers. Available at: Unlocking UV Stability in Polymers

[95] HSE blog (2023). Engineering controls – definitions, benefits and examples. Available at: Engineering Controls | Definitions, Benefits, And Examples

[96] TNO. An integrated risk management measure library. Available at: Projects | Overview | DIAMONDS 3

[97] National Institute for Occupational Safety and Health (NIOSH) (2024). About Hierarchy of Controls. Available at: About Hierarchy of Controls | Hierarchy of Controls | CDC

[98] European Commission (2010). Directive 2010/75/EU on industrial and livestock rearing emissions. Available at: EUR-Lex - 02010L0075-20240804 - EN - EUR-Lex

[99] European Commission (2024). Directive (EU) 2024/3019 concerning urban wastewater treatment. Available at: Directive (EU) 2024/3019 of the European Parliament and of the Council of 27 November 2024 concerning urban wastewater treatment (recast) (Text with EEA relevance)

baseline emissions in the EU. It can be reasonably expected that some, or all, of the measures presented below are used as standard in the large-scale manufacture of the products in scope of this Study, therefore leading to decreased emissions in the EU. These measures were identified following engagement with industry stakeholders between March and August 2025. The findings in this Section are not intended to present an exhaustive list of all RMMs used across industry, and only represent those highlighted during the stakeholder engagement process.

### 2.5.1 Local exhaust ventilation

Local exhaust ventilation (LEV) systems with integrated filtration play a critical role in controlling emissions from industrial manufacturing processes. LEV systems are designed to capture pollutants at, or near, their point of generation, primarily to prevent human exposures. LEV systems fitted with an air filter trap hazardous particles before the contents are discharged to the environment from the exhaust stack.[100] LEV systems operate on the following principles: dust and other contaminants are collected by the hood at the source of production, before being sucked into the system by the duct. The filters attached to the system clean the contaminated air, after which point, it is pushed to the exhaust stack by fans and the cleaned air is discharged.[101] Abatement efficiencies of these methods can reach up to 99%.[102] Owing to the low volatility of the substances in scope of this assessment, it is expected that LEV filtration methods will be most effective when capturing dusts, powders and/or particulate matter of polymers with the UV stabilisers incorporated into their matrix.

### 2.5.2 Industrial (on-site) wastewater treatment plant

Industrial wastewater treatment plants (IWWTP) reduce environmental emissions by reducing or removing contaminants before the water is re-used or discharged to the environment. The process is generally comprised of physical, chemical and/or biological processes. Large, easy to separate contaminants (i.e., physical objects, grit) are removed in a mechanical screening process, and specialist systems are used to separate fats, oil and grease.[103]

Secondary treatment of the wastewater involves biological processes, whereby microorganisms consume the pollutants and ideally break it down to carbon dioxide, other inorganics (e.g. phosphate, ammonia, nitrate) and even form new biomass. These processes can be aerated or anaerobic in order to provide the best removal options.[104]

The third treatment step usually comprises of a sewage sludge settlement process, which helps to get rid of all substances being adsorbed onto the sludge particles.

Academic studies have investigated the effectiveness of some wastewater treatment techniques for selected UV-light stabilisers. One study found that removal rates for UV-329 ranged between 68.2 – 85.2%, whilst efficiencies for UV-326 were higher (94.1 – 97%). Other substances in scope of this Study were not investigated.[105] Furthermore, in a previous survey on cosmetic UV filter elimination rates through a municipal sewage treatment plant process high removal efficiencies have been shown for highly adsorptive molecules which would be also applicable to the four phenolic benzotriazoles evaluated in this actual Study.[106]

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[100] Safety Culture (2024). A Comprehensive Guide to Local Exhaust Ventilation. Available at: Local Exhaust Ventilation: A Comprehensive Guide | SafetyCulture

[101] Safety Culture (2024). A Comprehensive Guide to Local Exhaust Ventilation. Available at: Local Exhaust Ventilation: A Comprehensive Guide | SafetyCulture

[102] European Commission (2016). Best Available Techniques (BAT) reference document for common waste water and waste gas treatment/ management systems in the chemical sector. Available at: Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector | EU-BRITE

[103] Engineer Fix (2025). How an Industrial Wastewater Treatment Plant Works. Available at: How an Industrial Wastewater Treatment Plant Works - Engineer Fix

[104] Engineer Fix (2025). How an Industrial Wastewater Treatment Plant Works. Available at: How an Industrial Wastewater Treatment Plant Works - Engineer Fix

[105] Sokolowska *et al.,* (2024). Comparison of benzotriazole ultraviolet stabilizers (BUVs) removal from wastewater after subsequent stages of sequencing batch reactor (SBR) treatment process, *Science of the Total Environment,* 1, 169813. Available at: https://doi.org/10.1016/j.scitotenv.2023.169813

[106] Pawlowski *et al,* (2025). Cosmetic UV filters used in sunscreens and their impact on corals put into perspective, *Environmental Sciences Europe*, 37, 173. Available at: https://doi.org/10.1186/s12302-025-01242-2

### 2.5.3 Wastewater incineration

Wastewater incineration is used broadly in Europe to remove contaminants from wastewater. The wastewater contaminants are oxidised with air at elevated temperatures (730 – 1,200 °C) to produce carbon dioxide, water and, depending on the constituents of the waste stream, other inorganic compounds. The abatement efficiency associated with wastewater incineration is >99%. This process produces flue-gases that may need additional treatment, depending on the content.[107]

### 2.5.4 Other identified measures

LEVs and IWWTPs were most commonly identified as engineering controls used to reduce emissions during the manufacture of products containing UV-light stabilisers. However, additional measures were also highlighted, that may not technically be considered engineering controls, but that also contribute to decreased emissions of UV-light stabilisers during these manufacturing processes.

Avoiding product discharges into sewers was identified as one way of limiting emissions to the environment. This directly reduces the mass of contaminants (in this case, UV-light stabilisers) entering wastewater treatment systems, thereby reducing the need for additional fourth treatment step. Capture of these pollutants and appropriate waste disposal is likely to lead to reduced environmental emissions overall.

Similarly, systematic cleaning of process equipment, floors and surrounding areas, combined with controlled disposal of waste residues, prevents the accidental release of contaminants and limits emissions to the environment.

Operation Clean Sweep is a voluntary, industry led initiative - now committed to by over 4,700 companies - that seeks to prevent the loss of plastic pellets, flakes and powders (e.g., those containing UV-light stabilisers) to the environment during manufacturing, handling, transport and processing.[108] The measures taken can be divided into three categories: source containment (e.g., use of enclosed transfer systems, spill-proof equipment design), capture and recovery (dedicated pellet capture systems, vacuum recovery systems) and infrastructure and site design measures ( e.g., stormwater management systems, wastewater pre-treatment, and material storage controls).[109] These measures prevent direct loss of polymer particles (e.g., UV-light stabilisers) into environmental compartments, reduce emissions to surface waters and WWTPs, and prevent accidental loss during extreme weather and routine cleaning.[110]

The engineering controls presented in this Section were identified from stakeholder inputs as being relevant to the manufacture of the products in scope of this assessment. These measures are therefore not intended to be comprehensive or representative of the entire industry. It is therefore reasonable to assume that more engineering controls may already be used in addition to those outlined above, leading to further reduction in emissions of UV-light stabilisers. The next section of the report outlines technically feasible measures, in addition to those in this Section, that may be used to limit the emissions of UV-light stabilisers. It is therefore possible that some of the following measures may already be used however, in the absence of further evidence, additional commentary on their current use is not presented.

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[107] European Commission (2016). Best Available Techniques (BAT) reference document for common waste water and waste gas treatment/ management systems in the chemical sector. Available at: Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector | EU-BRITE

[108] Operation Clean Sweep. OCS – About. Available at: About - Operation Clean Sweep

[109] Operation Clean Sweep. OCS: Objective zero pellet loss manual. Available at: OCS_Manual_EN.pdf

[110] Operation Clean Sweep. OCS: Objective zero pellet loss manual. Available at: OCS_Manual_EN.pdf

# 3. POTENTIAL RISK MANAGEMENT MEASURES AND EMISSIONS REDUCTION

This Section outlines potential risk management measures that could be implemented during the manufacture of products containing UV-light stabilisers, to further reduce emissions to the environment. It is acknowledged that some or all of these measures may already be used for specific processes and/or products in scope of this assessment, however, these were not identified during the stakeholder consultation exercise and are thus included in this Section as potential measures. See Appendix A1.7 for the methods used to identify potential RMMs.

The baseline emissions analysis presented in Section 2.4 is based on scenarios and assumptions, i.e., it does not assume an exact tonnage per substance and per sector is consumed in the EU. Similarly, due to limitations of the data inputs, the ERFs used result in a 'worst-case scenario' emissions analysis that does not assume the use of any RMMs. This report therefore does not draw conclusions on the exact emissions per substance and per sector. Similarly, the RMMs presented in this Section are discussed only in terms of their abatement efficiencies. A worked example is included for each compartment (air and water) to demonstrate potential emission reductions. However, detailed modelled reductions have not been performed owing to the wide variation in measures that could be used in future, or that may already be in use. Instead, the efficiencies should be reviewed when considering the potential volumes of reduced emissions.

### 3.1.1 Wastewater

Table 3-1 presents seven RMMs that were identified in addition to the existing RMMs already being used (Section 2.5) that could be implemented in future (if they are not already) to reduce emissions of UV-light stabilisers to wastewater. RMMs for the potential emissions to soil due to the application of treated sludge to land for agricultural purposes have not been considered.

The processes identified as potentially relevant for reducing wastewater emissions can be broadly categorised as physical, physico-chemical, chemical, or biological, offering a range of technologies that could further reduce emissions of UV-light stabilisers, where necessary. Physical measures rely on mechanical separation or filtration, physico-chemical measures combine physical and chemical processes to capture or transform pollutants, chemical measures use reactive substances to neutralise or degrade contaminants, and biological measures employ microorganisms to break down organic substances.[111]

An assessment of the applicability of these techniques for the most commonly identified manufacturing processes (Section 2.2 and sub-sections) is outlined in Table 3-1. For example, for extrusion and moulding processes, physical and physico-chemical methods are considered more feasible than biological methods, as there are usually low volumes of organic content released during these processes and biological waste treatment would not be considered cost effective.

Conversely, the manufacturing processes for the adhesives and coatings, paints and ink sectors tend to lead to higher emissions, owing to the more prevalent use of open manufacturing processes. As such, all processes were identified as being technically feasible, including biological treatment, oxidation, adsorption and stripping.

High abatement efficiencies are possible across all categories of RMM, though exact efficiencies will depend on the contaminant being removed. For example, chemical oxidation can achieve efficiencies up to 100%, whilst a biological activated sludge system can achieve efficiencies of 99%. The lowest reported efficiency was 90%, for physico-chemical adsorption processes. These abatement efficiencies are taken from publicly available sources, and it is acknowledged that these efficiencies may not always be achieved for the substances in scope of this assessment.

[111] European Commission (2016). Best Available Techniques (BAT) reference document for common waste water and waste gas treatment/ management systems in the chemical sector. Available at: [Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector | EU-BRITE]

Table 3-1: RMMs and their associated abatement efficiencies that may be implemented to reduce emissions to wastewater.[112]

| Risk management measure | Description | Potential abatement efficiency (%)[113] | Potentially applicable manufacturing processes |
|---|---|---|---|
| Physical – distillation/ rectification | Wastewater is heated until it vaporises, leaving behind low volatility/ higher boiling point contaminants. The vapour is cooled in a condenser and collected as liquid water. | 97.5 | Adhesives/ paints and coatings manufacture |
| Physical – nanofiltration | Semi-permeable membranes with small nano-sized pores allow water to pass through and prevent the passage or larger contaminants. The movement of water is driven by pressure differences across the membrane. | 99 | All processes |
| Physico-chemical – absorption | Contaminants dissolved in liquid (water) are bound to the surface of a solid substance with a high surface area that permits adsorption. | 90 | All processes |
| Physico-chemical – stripping | Stripping with steam to remove organic contaminants from the wastewater. | 99.5 – 99.75 | Adhesives/ paints and coatings manufacture |
| Chemical – oxidation | Wet oxidation with hydrogen peroxide. Organic matter is oxidised in wastewaters by hydroxyl radicals in the presence of a ferrous ion ($Fe^{2+}$ catalyst), in an acidic medium and mild conditions (100 – 150 °C, 2 – 4 bar). | 99 – 100 | All processes |
| Chemical – wastewater sludge incineration | Organic matter in the sludge is incinerated using thermal treatment, i.e., in a furnace using oxygen and temperatures above 850 °C. | 70-95%. | Adhesives/ paints and coatings manufacture |
| Biological – aerobic treatment | Oxygen and microorganisms break down organic pollutants in wastewater within an aeration tank. The organic contaminants are consumed by bacteria and resultant carbon dioxide, water, and biomass are produced. | 99 | Adhesives/ paints and coatings manufacture |
| Biological – activated sludge system | Soluble contaminants are removed from wastewater via adsorptive contact with biomass in a biological treatment system, followed by incineration of contaminated sewage sludge. | 95 | Adhesives/ paints and coatings manufacture |

**Emissions reduction estimate**

The emissions analysis presented in this report assumes a ‘worst-case scenario’, that is, it does not assume the use of any risk management measures to prevent or abate environmental emissions. Appendix 4 contains the detailed emissions estimates, disaggregated at the substance and sector level, to air and water in the EU-27 (Tables A-17 – A-20).

[112] TNO. An integrated risk management measure library. Available at: [Projects | Overview | DIAMONDS 3]
[113] TNO. An integrated risk management measure library. Available at: [Projects | Overview | DIAMONDS 3]

Using the central estimate from the 5,000 tonnes scenario, the modelled analysis estimated that 1.31 tonnes of UV-326 are released to water each year in the EU-27 due to the manufacture of adhesives and sealants. Table 3-1 above identified that all measures are applicable to the manufacturing processes for adhesives and sealants. Using 'distillation/ rectification' as a worked example, with an efficiency of 97.5%, this single technique would reduce emissions of UV-326 to water (in the EU-27, from the manufacture of adhesives and sealants) from 1.31 tonnes to 0.033 tonnes per year.

It is anticipated that multiple techniques may be used (or are already used) in conjunction to further reduce emissions.

### 3.1.2 Air

Similarly, Table 3-2 presents seven RMMs that were identified in addition to the existing RMMs already being used (Section 2.5) that could be implemented in future (if they are not already) to reduce emissions of UV-light stabilisers to air/ gas waste streams.

For this waste stream, most of the identified RMMs rely on physical measures (e.g., wet scrubbers, adsorption) to remove contaminants, e.g., the contaminant is reacted with or on a physical surface to produce a reaction by-product and 'clean' air.

The efficiencies of these measures are more varied compared to wastewater RMMs, though abatement efficiencies are typically still high, for example up to 99% for dry scrubbers, however they can be as low as 50% for wet electrostatic precipitators.

As with the wastewater measures, some RMMs are considered more feasible for certain manufacturing processes. The major form of emissions associated with typical plastics manufacturing processes are dust and particulates, where wet scrubbers and electrostatic precipitators are more viable. The low volumes of VOCs present during these processes suggests that the feasibility of adsorption and chemical scrubbers is mostly limited. Conversely, and as identified with wastewater RMMs, VOCs and solvents are a larger source of emissions in the adhesives and coatings, paints and inks sector(s), and as such adsorption technologies, wet/dry scrubbers and chemical scrubbers are all considered relevant. As noted in Table 3-2, alkaline scrubbers are only relevant for acidic gases and not for general VOCs or particulate.[114]

Table 3-2: RMMs and their associated abatement efficiencies that may be implemented to reduce emissions to air.[115]

| Risk management measure | Description | Potential abatement efficiency (%)[116] | Applicable manufacturing processes |
|---|---|---|---|
| Chemical – alkaline scrubber | Acid-forming components are reacted with a basic scrubbing liquid in a neutralisation reaction, to produce salts that can be re-processed. | 90 | Adhesives/ paints and coatings manufacture |

[114] European Commission (2016). Best Available Techniques (BAT) reference document for common waste water and waste gas treatment/ management systems in the chemical sector. Available at: Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector | EU-BRITE

[115] TNO. An integrated risk management measure library. Available at: Projects | Overview | DIAMONDS 3

[116] TNO. An integrated risk management measure library. Available at: Projects | Overview | DIAMONDS 3

| Risk management measure | Description | Potential abatement efficiency (%)[116] | Applicable manufacturing processes |
|---|---|---|---|
| Electro-physical – wet electrostatic precipitator | Waste gas is wet scrubbed to remove the organic contaminant (and dust), and is then passed through an electric field to collect the dust. | 50 | All processes |
| Physical – wet scrubber for dusts | Dust is removed from gas streams after coming into contact with a spray of water, scrubbing liquid, or a wetted surface. Dust particles collide with water droplets and are trapped in the scrubber, after which point clean gas exits the system. | 90 | All processes |
| Physical – dry scrubber (gas) | Contaminants are removed from waste gas or air in the absence of liquid. Waste gases are exposed to solid materials (e.g., activated carbon) that capture or react with pollutants, and then become solid waste. | 99 | Adhesives/ paints and coatings manufacture |
| Physical – semi-dry scrubber | The principle is the same as for dry scrubbing. In a semi-dry process, the selected adsorbent is added as a suspension or solution and water evaporation cools the gas stream. | 85 | Adhesives/ paints and coatings manufacture |
| Physical – wet scrubber for gas | Contaminated waste air streams are exposed to a liquid intended to absorb, dissolve or capture the contaminant. | 99 | All processes |
| Physical – adsorption | Contaminant molecules are bound onto the surface of the adsorbent. | 99 | Calendaring, adhesives/ paints and coatings manufacture |

**Emissions reduction estimate**

The emissions analysis presented in this report assumes a 'worst-case scenario', that is, it does not assume the use of any risk management measures to prevent or abate environmental emissions. Appendix 4 contains the detailed emissions estimates, disaggregated at the substance and sector level, to air and water in the EU-27 (Tables A-17 – A-20).

Using the central estimate from the 5,000 tonnes scenario, the modelled analysis estimated that 0.027 tonnes of UV-329 are released to air each year in the EU-27 due to the manufacture of mobility and automotive products.

Table 3-2 above identified that several measures are applicable to the manufacturing processes for adhesives and sealants. Using 'wet scrubber for physical dusts' as a worked example, with an efficiency of 90%, this single technique would reduce emissions of UV-329 to air (in the EU-27, from the manufacture of mobility and automotive parts) from 0.027 tonnes to 0.0027 tonnes per year.

It is anticipated that multiple techniques may be used (or are already used) in conjunction to further reduce these emissions further.

### 3.1.3 Conclusions on the potential risk management measures

The engineering controls identified in this assessment represent a range of technically feasible options for reducing emissions of UV-light stabilisers to air, soil and water, and for which manufacturing processes they may apply to. Many of these techniques are widely used throughout the chemical industry as standard risk management measures implemented into manufacturing processes. It is anticipated that many of these measures are already in place in the manufacturing processes identified as relevant for this Study, though no specific confirmation is available based on methodological limitations at the time of drafting. However, if these methods are not already used, their implementation into current processes would serve as one way that industry could further reduce emissions of UV-light stabilisers to the environment.

As noted in Section 2.5, some abatement techniques already have efficiencies exceeding 99% (wastewater incineration). However, the research presented in this Section indicates that there are several additional measures that could be introduced and/or optimised with similarly high abatement efficiencies, often in the range of 90-100%. As the emissions estimation assumes a worst case i.e. an absence of risk management measures, it is anticipated that the current use or future implementation of these measures could further reduce the emissions of UV-light stabilisers from the manufacture of the products in scope to approximately 10% of the worst-case scenario estimates.

# 4. CONCLUSIONS

UV-light stabilisers are used across a wide range of important sectors and end applications, primarily to protect materials from the damaging effects of UV radiation. Their use across these applications, including plastics, coatings, textiles and adhesives, extends the lifespan of products, with economic and environmental benefits. The uses identified in this Study are critical to society as they underpin essential infrastructure, mobility, communication, energy generation, consumer goods and industrial production. As such, these sectors contribute to the functioning of economic markets, public safety, and the transition to a more sustainable and resilient future/economy as they are used to extend the lifespan of products.[117] Products that last longer and need to be replaced less frequently reduce raw material extraction and manufacturing impacts, produce less waste, and contribute to an enhanced circular economy.

At the global level, the United Nations Sustainable Development Goals (UN SDGs) are also relevant, notably those related to human health and well-being, environmental protection, sustainable production and consumption, climate action, and ecosystem conservation. The development and use of durable and resilient materials can support progress towards these objectives by contributing to resource efficiency, product longevity, and reduced environmental impacts.[118] The incorporation of UV-light stabilisers into different polymers and products contributes to the achievement of these goals.

This Study highlights the diversity of uses of the UV-light stabilisers in scope, with almost all sectors using all four substances in some capacity (with some exceptions). The emissions analysis conducted in this Study, based on worst-case assumptions, indicates that emissions for all four substances may be of a similar magnitude, ranging from a cumulative lower bound of 0.6 tonnes per year up to an upper bound of 6 tonnes per year in the EU. Emissions at the local level (as a proportion of the annual, regional emissions) are estimated to be in the order of grams per day.

The largest emissions were observed for the adhesives and sealants, and coatings, paints and inks sectors, driven primarily by differences in the approach to estimate emissions using ERFs from standard plastic additives (all other sectors) and ECHA-specific spERCs. Emissions to water were identified as the primary driver of release in these sectors, with volumes being approximately 6x higher compared to air.

Similarly, higher emissions are expected to occur in these sectors due to the manufacturing processes used (i.e., open processes), and because the UV-light stabilisers remain largely unbound in liquid formulations. This can lead to higher volumes of emissions compared to solid plastic articles. These figures are based on modelled assumptions and scenarios using standard regulatory methodologies, in the absence of industry-specific data.

Despite a small sample of data, several risk management measures were identified that are considered by default to apply to the processes used to manufacture the products in scope of this assessment. These measures, such as the use of filters on local exhaust ventilation devices, or the treatment of water at industrial plants, capture and/or prevent the release of UV-light stabilisers at source. The efficiencies of these measures are typically in the 90-99% range, indicating that they are highly effective, and the ‘worst-case scenario’ emissions calculated in this Study are indeed an overestimation. If these measures are universally used and implemented as standard good manufacturing practice, the emissions from UV-light stabilisers during these processes may be minimal.

Additional technical factors are also expected to contribute to a reduction in overall emissions, such as the nature of the manufacturing processes used (e.g., predominantly closed systems), as well as the low volatility of the UV-light stabilisers that are predominantly bound into a polymer matrix. Overall, the indicative results presented in this report suggest that very low quantities of UV-light stabilisers are expected to be emitted to the environment during the manufacture of the products in scope of this assessment. Further potential risk management measures are also available (and may currently be used), also with efficiencies in the 80-100% range, indicating that emissions could be further reduced in future if required.

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[117] Mordor Intelligence (2025). UV stabilisers market size and share analysis – growth trends and forecasts (2025-2030). Available at: UV Stabilizers Market Size, Growth Drivers, Demand & Forecast 2030

[118] United Nations. The 17 Goals. Available at: THE 17 GOALS | Sustainable Development

This Study provides an evidence base that could be drawn upon during the next stages of the regulatory process as it identifies which sectors contribute most to emissions and where risk management efforts could be focused to be the most effective. By highlighting sector-specific emission patterns, the results could inform the prioritisation of regulatory measures, noting that the manufacturing processes and uses outlined in this Study are generally anticipated to be contained and controlled. Similarly, the results of this Study could be used to inform a tailored approach to restrictions and/or exemptions in subsequent regulatory actions.

Published regulatory documents have concluded that consumer and widespread professional uses are the primary source of emissions due to non-contained uses that cannot be avoided. Consumer uses identified through REACH registration data include adhesives and sealants, air care products, anti-freeze products, disinfectants and cleaning products, coatings and paints, metal surface treatment products, inks and toners, perfumes and fragrances, and cosmetics and personal care products. The potential emissions from these uses were not explored in this report and should be assessed on a case-by-case basis.

As noted, the proposed restriction of octocrilene highlighted that only cosmetic uses were deemed to pose a risk, and risks were not identified in preparations that contain octocrilene as an additive, in the production of plastic additives, inclusion into a matrix, in adhesives and coatings, and the wide dispersive use of plastics. These insights may be relevant to consider alongside the findings of this report when determining future regulatory action.

To conclude, this Study identified a range of critical uses of UV-light stabilisers that contribute directly to the European economy and broader sustainability goals. The analysis conducted found that releases of UV-light stabilisers are higher when their uses are uncontrolled (as in consumer products), when end-products are manufactured using open processes, and/ or when the final product contains UV-light stabilisers that are not bound into a polymer matrix (e.g., in liquid formulations). Future work could investigate emissions from consumer uses, to determine the extent to which uncontrolled emissions present a risk to human health and/or the environment. In contrast, emissions from industrial processes in the EU-27 are generally well-contained through the use of risk management measures. Where these measures are not implemented yet, industry could take action to further reduce the emissions of UV-light stabilisers into the European environment.

# Appendices

# Appendix 1 Methodology

This Appendix provides further detail on the methodologies used in this Study. This is broken down into the following subheadings:

- A1.1 Literature review
- A1.2 Stakeholder consultation
    - A1.2.1 Data collection template
    - A1.2.2 Interviews with ELiSANA members
- A1.3 Assignment of tonnage estimates per substance
- A1.4 Allocation of substance tonnages to each sector (market share)
- A1.5 Determination of the proportion of closed, open and partially open manufacturing processes
- A1.6 Baseline estimation
    - A1.6.1 Methods
    - A1.6.2 Estimating regional and local releases
    - A1.6.3 Input emission release factors
- A1.7 Identification of potential risk management measures

### A1.1 Literature review

Desk research was conducted, primarily through January and February 2025, but iterated over the duration of the Study, to gather evidence that could support the risk management and emissions analysis of UV-light stabilisers in the EU-27. This was comprised of a review of existing studies and targeted desk research, which focused on identifying literature and/or evidence across certain themes, agreed with ELiSANA, including:

- The use(s) of the four UV-light stabilisers in scope of the assessment, across the 10 sectors in scope;
- Manufacturing processes associated with the identified uses;
- Where available, information on emissions (sources, pathways, quantified emissions) associated with the manufacture of the identified products;
- Information on risk management measures that are currently used in these processes;
- Broader information on risk management measures, to support the findings in Section 3.

A targeted search strategy was developed to ensure all sectors and substances were covered in the literature searches and all findings and progress were recorded in an Excel database. For example, key word searches were performed such as 'UV-X' + 'uses' + 'sector' to initially identify information on generic uses and functionality across different databases – mainly Google, Science Direct and Scholar. As this Study focused on industrial and professional uses, academic publications were reviewed and considered less relevant where the results described Low Technical Readiness (TRL) technologies. Typically, industry publications and blogs were favoured over academic publications.

This process was repeated with all sectors and substances. Once the uses had been identified, a second phase of searches was conducted to identify the associated manufacturing processes, and added to the Excel database.

The same process was repeated to identify sources on emissions from manufacturing processes. Due to the specific scoping dimensions of this Study (i.e., emissions from the manufacture of products containing UV-light stabilisers), it was anticipated that few relevant sources would be identified.

Regulatory documents were also sought to obtain information on the regulatory history, registered uses and potential environmental releases of these substances in the EU. Repositories such as the ECHA CHEM

Database[119], the Assessment of Regulatory Needs list[120], the list of restriction intentions[121], and the ECHA use maps library[122] were all reviewed and relevant documents identified.

Supporting information received from ELiSANA members was also additionally reviewed and used in this Study.

## A1.2 Stakeholder Consultation

### *A1.2.1 Data collection template*

A bespoke, Excel-based data collection template was developed and launched on 24th March and closed, after extending the deadline, on 30th May. The stakeholder consultation exercise targeted ELiSANA members and downstream users of UV-light stabilisers across the sectors in scope of the Study.

When completing the Excel data collection template, respondents were asked to provide data on their organisation, manufacture and import of the UV-light stabilisers, information on uses, manufacturing processes, environmental emissions, current risk management measures, and potential risk management measures. More specifically, the template was structured in six main parts:

- Company information, asking for basic information of about the responding organisation, such as size and contact details.
- Manufacture and import, asking whether respondents manufactured and/ or imported each of the four UV-light stabilisers in the EU-27, and in what volumes.
- Four data collection tabs, one per substance, asking respondents to outline the uses, manufacturing processes, emissions and RMMs for each identified for use.

Table A-1 summarises the number of responses received per substance and per sector. 12 responses were received covering several sectors and substances, with some quantification of production volumes. Manufacturing process descriptions were included in most responses. However, with some exceptions, the minimum response threshold as per the Cefic statistical rules was not met.

The data was processed and some insights, such as uses and manufacturing processes that could be externally validated with literature, were taken forward for use in the report. However, most information was discarded and not taken forward, owing to the need to protect confidential business information. It is worth noting that, whilst some substances/ sectors met the minimum number of responses, not all responses included sufficient volumes to proceed. As such, an alternative method was sought that could be applied to all sectors and substances.

Table A-1: Number of responses received per sector and per substance.

| Sector | UV-326 | UV-329 | UV-234 | UV-P |
|---|---|---|---|---|
| **Renewable energy** | | | 1 | |
| **Building and construction** | 3 | | 6 | 2 |
| **Electronics** | 1 | | 3 | |
| **Coatings, paints and inks** | | | | |
| **Adhesives and sealants** | | | | |
| **Mobility and automotive** | 5 | 3 | 7 | 2 |
| **Textiles and fibres** | | | | |

[119] ECHA CHEM. ECHA Chemicals Database. Available at: ECHA CHEM

[120] European Chemicals Agency. Assessment of regulatory needs list benzotriazole. Available at: Assessment of regulatory needs list - ECHA [date accessed 19.11.2025]

[121] European Chemicals Agency. Registry of restriction intentions until outcome. Available at: Registry of restriction intentions until outcome - ECHA [date accessed 19.11.2025]

[122] European Chemicals Agency. Use maps. Available at: Use maps - ECHA

| Sector | UV-326 | UV-329 | UV-234 | UV-P |
|---|---|---|---|---|
| **Wire and cable** | | | 2 | |
| **Production of alkyl derivatives** | | | | |
| **Packaging** | 2 | | 3 | |
| **Sports equipment** | 1 | | | |

### *A1.2.2 Interviews with ELiSANA members*

In the absence of sufficient data obtained through the consultation process, a mitigation strategy was proposed to interview ELiSANA members to fill the remaining data gaps needed to proceed with the analysis. Interviews focused on obtaining information on:

- The volumes of each substance manufactured and/or imported into the EU-27.
- The proportion of each substance used in each sector, to determine an approximate market share.
- Manufacturing processes.
- Risk management measures that are currently used, and additional RMMs that could be used in future.

Two ELiSANA members were available for interview. The data obtained from these interviews could not be used without further processing, in line with Cefic's statistical rules. Approval from Cefic lawyers was sought and granted to proceed with an alternative methodology, outlined below.

## A1.3 Assignment of tonnage estimates per substance

According to publicly available data, there are between 12 and 17 registrants for each of the UV-light stabilisers in the EU (UV-P: 12; UV-329 and UV-234: 15; UV-326: 17).[123] The Light Stabilisers and Antioxidants (LiSAO) REACH Consortium requested tonnage data from registrants for the last two years (2023 and 2024). However, information from responses to the LiSAO data request either did not meet the Cefic statistic rules threshold, or did not exceed more than 33% coverage of the market (in terms of number of operators). As such, it was agreed with ELiSANA and Cefic lawyers that only publicly available data should be used.

Each substance is manufactured and imported into the EU between 1,000 – 10,000 tonnes per annum.[124] In the absence of specific industry data, incremental tonnage band scenarios were taken forward to be used in the emissions analysis: 1,000, 2,500, 5,000, 7,500 and 10,000 tonnes. The emissions analysis assumes that this is the tonnage of UV-light stabilisers consumed to produce the relevant products in scope, and is not the final volume of the overall products manufactured.

## A1.4 Allocation of substance tonnages to each sector (market share)

Several data sources were drawn upon and iterative steps taken to allocate a market share (i.e., a proportion of tonnage to each substance), as follows:

- Firstly, ELiSANA members were asked to share confidential business information for their organisation, for all substances and sectors, on a qualitative scale. **Very low = 0-19%; low = 20-39%; medium = 40-59%; high = 60-79%; very high = 80-100%.**
- Large percentage ranges were selected to protect confidential business information, whilst acknowledging it reduces the applicability of the subsequent analysis.
- The confidential business information shared by ELiSANA members was reviewed internally and "averaged" (qualitatively) to produce a first estimate of market share per substance.
- Following this, key economic market reports were identified and reviewed to identify the broader, key sectors of use for UV-light stabilisers, and to obtain any insights on the proportion of each market.

[123] ECHA CHEM. ECHA Chemicals Database. Available at: ECHA CHEM
[124] ECHA CHEM. ECHA Chemicals Database. Available at: ECHA CHEM

[125,126,127,128] These reports were for generic UV-light stabiliser markets but were considered a sufficient proxy for the substances in scope of this Study.

- Qualitative assignments were updated where necessary to reflect the leading sectors in the market data.
- Following this, insights from ELiSANA members about the broader industry were revisited (not specific to their business operations) and further amendments were made to the qualitative allocations.
- The qualitative allocations were converted to the associated quantitative ranges. A validation check was done to ensure the summed lower bounds of each substance did not exceed 100%.
- Following this, allocations were readjusted (based on an understanding of major versus minor markets) to ensure the quantitative sum of the lower bounds for each substance was valid (<100%).

The final iteration of this exercise is presented in Section 2.2.3 and repeated in Table A-2 below.

Table A-2: Estimated market share allocation per substance and per sector.

| Sector | UV-326 (tonnes) | UV-329 (tonnes) | UV-234 (tonnes) | UV-P (tonnes) |
|---|---|---|---|---|
| Adhesives and sealants | Very low | Very low | Very low | Very low |
| Building and construction | Low | Low | Low | Low |
| Coatings, paints and inks | Very low | Very low | Very low | Very low |
| Electronics | Very low | Very low | Very low | Very low |
| Mobility and automotive | Very low | Low | Low | Very low |
| Packaging | Very low | Very low | Very low | Very low |
| Renewable energy | Very low | Very low | Very low | Very low |
| Sports equipment | Very low | Very low | Very low | Very low |
| Textiles and fibres | Very low | Very low | Very low | Very low |
| Wire and cable | Very low | Very low | Very low | Very low |

## A1.5 Determination of the proportion of closed, open and partially open manufacturing processes

Variation in the ERFs used in this assessment derives from differences in emissions that occur during closed, open and partially open manufacturing processes. As such, the final step to take before the baseline emissions can be estimated is to determine the relevant proportion of these processes for each substance and each sector. As the analysis in this report is conducted at a high-level, it is the variation in the proportion of these processes, and variation in the market share, that drives nuance in emissions between substances and sectors.

[125] Mordor Intelligence (2025). UV stabilisers market size and share analysis – growth trends and forecasts (2025-2030). Available at: UV Stabilizers Market Size, Growth Drivers, Demand & Forecast 2030

[126] Fortune Business Insights (2025). UV Stabilizers Market Size, Share & Industry Analysis, By Type 2025-2032. Available at: UV Stabilizers Market Size & Share | Global Report [2032]

[127] Metatech Insights (2025). UV Stabilizers Market By Type, By Application, By Polymer Type, By End-user, Global Market Size, Segmental analysis, Regional Overview, Company share analysis, Leading Company Profiles And Market Forecast, 2025 – 2035. Available at: UV Stabilizers Market Share, Size, Trend & Growth 2025-2035

[128] Stats & Research (2025). The Global UV Light Stabilizers Market is segmented By Type, By Application, By End-Use, and By Region. Available at: UV Light Stabilizers Market Size, Share And Forecasts 2032

The proportion of open and closed processes was determined by reviewing the type and number of products per category manufactured using different processes, as well as considering the information provided in technical reports (for example, the OECD ESD on Plastic Additives states that 55% of polymers are converted using closed processes) and insights from industry experts. Table A-3 presents the assumptions taken forward for this analysis for all sectors except adhesives and sealants, and coatings, paints and inks. The assumptions for the remaining sectors are outlined in Appendix A1.6.1 and A1.6.2.

Table A-3: Allocation of open, closed and partially open processes used in the emissions analysis, presented by substance and by sector.

| Sector | Substance | Proportion of open processes (%) | Proportion of closed processes (%) | Proportion of partially open processes (%) |
|---|---|---|---|---|
| Building and construction | UV-326 | 10 | 85 | 5 |
| | UV-329 | 10 | 90 | |
| | UV-234 | | 100 | |
| | UV-P | 20 | 80 | |
| Electronics | UV-326 | | 100 | |
| | UV-329 | | 100 | |
| | UV-234 | 10 | 90 | |
| | UV-P | | 100 | |
| Mobility and automotive | UV-326 | 20 | 80 | |
| | UV-329 | 20 | 80 | |
| | UV-234 | 10 | 90 | |
| | UV-P | 5 | 95 | |
| Packaging | UV-326 | | 100 | |
| | UV-329 | | 100 | |
| | UV-234 | | 100 | |
| | UV-P | | 100 | |
| Renewable energy | UV-326 | *No identified uses* | | |
| | UV-329 | *No identified uses* | | |
| | UV-234 | | 100 | |
| | UV-P | | 100 | |
| Textiles and fibres | UV-326 | 100 | | |
| | UV-329 | *No identified uses* | | |
| | UV-234 | | | 100 |
| | UV-P | 50 | | 50 |
| Sports equipment | UV-326 | | | 100 |
| | UV-329 | *No identified uses* | | |
| | UV-234 | | 100 | |

| Sector | Substance | Proportion of open processes (%) | Proportion of closed processes (%) | Proportion of partially open processes (%) |
|---|---|---|---|---|
| | UV-P | *No identified uses* | | |
| Wire and cable | UV-326 | | 33 | 66 |
| | UV-329 | | 100 | |
| | UV-234 | | 25 | 75 |
| | UV-P | *No identified uses* | | |

## A1.6 Baseline Estimation

### *A1.6.1 Methods*

Based on the availability of data throughout this project, the baseline emissions were estimated using a standardised method, combining emission release factors derived from OECD Emission Scenario Documents (ESDs) and specific Environmental Release Categories (spERCs). This approach follows established regulatory guidance to ensure consistency, transparency and comparability with chemical safety assessments conducted under REACH and related EU frameworks.

The OECD ESD on Plastic Additives was used as a primary source to estimate emissions of UV-light stabilisers from solid plastic articles manufactured using different processes. As such, this document was used as the basis for analysis across all sectors, except for adhesives and sealants, and coatings, paints and inks, where more suitable sources were required and were available (see below). This ESD is considered directly relevant as it includes "UV and weathering stabilisers" as a defined group and provides emission release factors for the conversion of polymers into finished articles, as per the processes outlined in Section 2.2.2.

OECD ESDs were also reviewed for the Adhesives and the Coating Industry sectors.[129,130] However, ECHA spERCs were available for these sectors. These documents, and the associated ERFs, were used preferentially over the OECD ESDs (though noting the spERCs derive from the OECD documents) as they provide more realistic, sector-specific emissions factors based on industry data and operational conditions.[131]

For the adhesives and sealants, and coatings, paints and inks sectors the following spERCs were used for the emissions analysis:

- FEICA/ EFCC spERC 2.1a.v3 – Solvent-borne / solvent-less adhesives/ sealants – non-volatiles.[132]
- FEICE/ EFCC spERC 2.2b.v3 – Water-borne adhesives / sealants – non-volatiles.[133]
- CEPE spERC 2.1c.v2 – Formulation of organic solvent-borne coatings and inks – non-volatile.[134]
- CEPE spERC 2.2c.v1 – Formulation of water-borne coatings and inks – non-volatile.[135]
- CEPE spERC 2.3a v.1 – Formulation of powder coatings and inks – non-volatile.[136]

[129] OECD (2009). OECD Emission Scenario Document on Adhesive Formulation. Available at: Adhesive Formulation (EN)

[130] OECD (2009). OECD Emission Scenario Document on Coating Industry. Available at: Coating Industry (Paints, Lacquers and Varnishes) (EN)

[131] European Chemicals Agency. Use maps. Available at: Use maps - ECHA

[132] FEICA (2017). Specific Environmental Release Categories (SPERCs) for the formulation of adhesives, sealants and construction chemical products. Available at: bbae324e-07b4-5dac-0382-83152e16684e

[133] FEICA (2017). Specific Environmental Release Categories (SPERCs) for the formulation of adhesives, sealants and construction chemical products. Available at: bbae324e-07b4-5dac-0382-83152e16684e

[134] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

[135] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

[136] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

For the adhesives sector, the two formulation processes (water-borne, solvent-borne) were used equally for the emissions analysis, and a 50% weighting for each ERF was applied. Similarly, for the coatings, paints and inks sector, the three formulation processes (solvent-borne, water-borne, powder) were considered equally applicable for the emissions analysis, and a 33% weighting for each ERF was applied.

Emissions were calculated for each environmental compartment by applying the relevant ERFs (see Appendix A1.6.3, below) to the estimated tonnage data generated through the determination of substance tonnages and sector market shares. Five emissions scenarios were modelled (1,000, 2,500, 5,000, 7,500 and 10,000 tonnes). For each scenario, a lower, central and upper bound of the market share allocation was used to calculate an equivalent tonnage and used in the final emissions calculation.

**Example**

For the packaging sector, UV-326 was allocated a 'very low' share of the market, i.e., between 0-19% of the market. The lower, central and upper bounds were calculated using this allocation – 1%, 10% and 19%.

For the 1,000 tonnes scenario, the calculations were as follows:

1% → 10 tonnes
10% → 100 tonnes
19% → 190 tonnes

This was repeated for each tonnage scenario (2,500, 5,000, 7,500 and 10,000) and for each sector and substance.

These calculations yielded a baseline estimate of releases under typical operating conditions before the application of risk management measures. The scenario-based analysis and the lower, central and upper bounds increase granularity in the baseline emissions analysis.

### *A1.6.2 Estimating regional and local releases*

The annual estimated emissions (tonnes per year) were used to calculate local release estimates in kilograms per day, based on the methods outlined in the ECHA R.16 guidance document.[137] A simplified approach was used based on the following assumptions:

- There are 365 release days per year.
- Regional releases equate to 10% of the EU-27 releases.
- Local releases equate to 10% of the regional releases.
- "Local" level assumes a standard town with 10,000 inhabitants.
- The local level volumes are those reaching a standard biological treatment plant.
- The final value was converted to grams per day.

Following the calculation of baseline emissions, individual results were aggregated across the relevant uses and environmental compartments to determine total baseline emissions for UV-light stabilisers at the EU-level. The results of this analysis are presented in Section 2.4.

### *A1.6.3 Input Emission Release Factors*

*Plastic Additives*

The ERFs used for the emissions analysis derive from three sources – the OECD ESD on Plastic Additives, and the respective spERCs for the adhesives and coatings sector. For plastic additives, the ERFs taken forward are from Section 12 of the OECD ESD on 'UV and other weathering stabilisers', specifically for low volatility substances in conversion processes.

[137] European Chemicals Agency (2016). Guidance on information requirements and Chemical Safety Assessment. Chapter R.16: Environmental exposure assessment. Available at: Draft_R.16_V3.0

The OECD ESD assumes that losses will initially be to air at elevated temperatures, but subsequent condensation could result in losses to liquid waste. The document assumes 50% of emissions are to air and 50% are to waste. There is no consideration given to emissions for soil. Table A-4 summarises the figures used in the analysis. For the purpose of this Study, it is assumed these processes happen below 200 °C. For processes carried out significantly above 200 °C, the OECD ESD recommends multiplying the emissions factors by 10x.

The ERFs for both receiving compartment are the same for each process. As such, the calculated emissions for air will be equal to the calculated emissions for water.

Table A-4: Summary of ERFs used for plastic conversion processes.

| Process | Release factor to water (%) | Release factor to air (%) |
|---|---|---|
| **Open processes solid articles** | 0.005 | 0.005 |
| **Open processes foamed articles** | 0.01 | 0.01 |
| **Partially open processes** | 0.003 | 0.003 |
| **Closed processes** | 0.001 | 0.001 |

*Adhesives*

The following spERCs were used for the adhesives sector:

- FEICA/ EFCC spERC 2.1a.v3 – Solvent-borne / solvent-less adhesives/ sealants – non-volatiles.[138]
- FEICE/ EFCC spERC 2.2b.v3 – Water-borne adhesives / sealants – non-volatiles.[139]

The non-volatile ERFs were selected based on the properties of the four UV-light stabilisers in scope of the assessment. Table A-5 summarises the ERFs used for solvent-borne/ solvent-less and water-borne adhesives and sealants. For this analysis, it is assumed that both processes are used equally.

Table A-5: Summary of ERFs used for adhesives and sealants.

| Type of adhesive | Release factor to water (%) | Release factor to air (%) |
|---|---|---|
| **Solvent-borne/ solvent-less** | 0.02 | 0.08 |
| **Water-borne** | 0.505 | 0.0097 |

*Coatings, paints and inks*

The following spERCs were used for the coatings, paints and inks sector:

- CEPE spERC 2.1c.v2 – Formulation of organic solvent-borne coatings and inks – non-volatile.[140]
- CEPE spERC 2.2c.v2 – Formulation of water-borne coatings and inks – non-volatile.[141]

[138] FEICA (2017). Specific Environmental Release Categories (SPERCs) for the formulation of adhesives, sealants and construction chemical products. Available at: bbae324e-07b4-5dac-0382-83152e16684e

[139] FEICA (2017). Specific Environmental Release Categories (SPERCs) for the formulation of adhesives, sealants and construction chemical products. Available at: bbae324e-07b4-5dac-0382-83152e16684e

[140] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

[141] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

- CEPE spERC 2.3a.v.2 – Formulation of powder coatings and inks – non-volatile.[142]

The non-volatile ERFs were selected based on the properties of the four UV-light stabilisers in scope of the assessment. Table A-6 summarises the ERFs used for solvent-borne, water-borne and powder coatings and inks. For this analysis, it is assumed all processes are used equally.

Table A-6: Summary of ERFs used for coatings, paints and inks.

| Type of coating | Release factor to water (%) | Release factor to air (%) |
|---|---|---|
| **Organic solvent borne liquid coatings and inks** | 0.005 | 0.0095 |
| **Water-borne coatings and inks** | 0.25 | 0.0097 |
| **Powder coatings and inks** | 0.52 | 0.08 |

### A1.7 Identification of potential risk management measures

A range of sources was used to determine which RMMs may be technically feasible to implement, including Best Available Techniques Reference Documents (BREF, with specific considerations for relevance to the chemical industry)[143], the Cefic RMM library[144] and the Diamonds 3 software Exposure Control Efficacy Library (ECEL).[145] The Cefic RMM library was consulted to develop insights on sector-specific RMMs, however, the sector-specific information outlined within the database pertains to human health RMMs only and thus the RMMs are not presented in this Study.

To determine technically feasible RMMs, search filters were applied in the Diamonds ECEL software to identify measures that are applicable for a) low volatility substances and b) different forms of emissions (e.g., dust, gas). All forms of emissions were in scope. Expert judgement was applied to determine the relevance of each measure (e.g., which BREF it was sourced from, whether the targeted pollutant was of relevance) and the results, including the associated efficiencies, were collated in a table.

[142] CEPE (2020). Specific Environmental Release Categories (SPERCs) for formulation of liquid and powder coatings. Available at: b430653f-e2f1-e24e-38b7-25ecd25298b2

[143] European Commission. BAT reference documents. Available at: BAT reference documents | EU-BRITE

[144] Cefic. Risk management measures (RMM). Available at: Risk management measures (RMM) - cefic

[145] TNO. An integrated risk management measure library. Available at: Projects | Overview | DIAMONDS 3

# Appendix 2 Identified Uses and Substance Mapping

This Appendix includes summary tables of all uses identified in the desk-based research and stakeholder consultation exercise, alongside a mapping of which UV-light stabilisers are used.

**Adhesives and sealants**

Table A-7: Uses identified through literature searches and stakeholder engagement for the adhesives and sealants sector.

| Use | Substance |
|---|---|
| Generic adhesives | UV-234, UV-326, UV-329, UV-P |
| Pressure sensitive adhesives | UV-326 |
| Hot melt adhesives | UV-326 |

**Building and construction**

Table A-8: Uses identified through literature searches and stakeholder engagement for the building and construction sector.

| Use | Substance |
|---|---|
| Membranes: including roofing membranes; PVC coated fabrics and membranes | UV-234, UV-P |
| Interlayer films used for the production of laminated safety glass | UV-234, UV-326 |
| Masterbatch/ liquid colours for furniture manufacturers (Plain edgebanding and panels) | UV-234, UV-P |
| Glazing (window glass lamination, PMMA glazing) | UV-234, UV-329, UV-P |
| Generic plastic articles | UV-234 |
| Pipes and fittings: PEX pipes, PP pressure pipes, uPVC pipes | UV-326, UV-P |
| Window and door profiles: rigid PVC film or profile | UV-326 |
| Decking and fencing: PVC-based wood/plastic composites | UV-326, UV-P |
| PP building and construction fibres | UV-326 |
| Generic construction appliances | UV-326, UV-329 |
| Flooring | UV-326 |
| Wall panels | UV-326 |
| WPV or PVC foam board | UV-326 |
| TPE - generic | UV-326, UV-329 |
| Moulding | UV-329 |
| Sheet | UV-329 |
| Signs | UV-329 |
| Membranes: PVC coated fabrics and membranes | UV-P |

### Coatings, paints and inks

Table A-9: Uses identified through literature searches and stakeholder engagement for the coatings, paints and inks sector.

| Use | Substance |
|---|---|
| Wood coatings | Specific substance not identified* |
| Coatings for wind turbines | Specific substance not identified* |
| Coatings for vehicle paints | UV-234 |
| Coatings for window blinds | Specific substance not identified* |
| Industrial coatings | UV-234 |
| Coatings - generic | UV-234, UV-326 |
| High performance coatings | UV-234 |
| External protective coatings | UV-326 |
| Architectural coatings - generic | UV-326 |
| Coatings for plastics and paint | UV-329 |
| REACH identified use (not specified) | UV-P |

* Application was identified but not taken forward for analysis.

### Electronics

Table A-10: Uses identified through literature searches and stakeholder engagement for the electronics sector.

| Use | Substance |
|---|---|
| Plastic films in LED touch panels | Specific substance not identified* |
| Housing and frames - generic | UV-234, UV-326, UV-329 |
| Connectors | UV-234 |
| Solar panels | UV-234 |
| Housings - consumer electronics | UV-234, UV-P |
| Housings - power tools | UV-234, UV-P |
| Housings - components | UV-234, UV-329, UV-P |
| Appliances - white goods | UV-234, UV-P |
| Wire and cable | UV-234 |
| Photovoltaics - electrical components, frames, wire and cable, elastomers for jackets | UV-234 |
| Handy cover | UV-234 |
| PC housings and frames | UV-234, UV-329 |
| Housings - small appliances | UV-326 |
| Housings - wire and cable | UV-326 |
| Housings - TPU for jackets | UV-326 |
| TPE - generic | UV-326 |
| Lighting | UV-329 |
| Electrical components | UV-329 |

* Application was identified but not taken forward for analysis.

**Mobility and automotive**

Table A-11: Uses identified through literature searches and stakeholder engagement for the mobility and automotive sector.

| Use | Substance |
|---|---|
| Housing and frames - generic | UV-234, UV-326, UV-329 |
| Automotive parts - generic | UV-234, UV-329 |
| Bumpers | UV-234, UV-P |
| Dashboards | UV-234 |
| Door trims | UV-234 |
| Air bags | UV-234 |
| Instrument panels | UV-234 |
| Headlamp lenses | UV-234 |
| Thermoplasts | UV-234, UV-326, UV-329, UV-P |
| Paints, coatings and adhesives | UV-234, UV-326, UV-329, UV-P |
| Glazing (including laminated safety glass) | UV-234, UV-326 |
| Interiors | UV-234, UV-329 |
| Windshields | UV-326 |
| Windows - roof, side, back | UV-326 |
| Elastomers | UV-326, UV-329, UV-P |
| Rubbers, adhesives, covers, lubricants | UV-326 |
| TPE - generic | UV-326 |
| Auto applications | UV-329 |
| Lamps | UV-329 |
| Blinkers | UV-329 |
| Covers | UV-329, UV-P |
| Flaps | UV-329, UV-P |
| Mirror housings | UV-P |
| Trims | UV-P |
| Compartments | UV-P |
| Cables | UV-P |
| Lids | UV-P |
| Panels | UV-P |
| Sun visors | UV-P |

**Packaging**

Table A-12: Uses identified through literature searches and stakeholder engagement for the packaging sector.

| Use | Substance |
|---|---|
| Printing and packaging | UV-234 |

| Use | Substance |
|---|---|
| Packaging materials - generic | UV-234, UV-P |
| Bottles | UV-234 |
| Food packaging boxes | UV-234, UV-329 |
| Packaging of pallets of goods by stretch hood - only for outdoor storage. Hood must be transparent to identify products inside, and read e.g. Barcodes. | UV-234, UV-326 |
| Polypropylene and polyethylene film & thin wall packaging | UV-326, UV-P |
| Heavy duty packaging | UV-326 |
| PP/HDPE returnable crates | UV-326 |
| Bottle caps | UV-326, UV-P |
| Film and thin wall | UV-326 |
| Heavy duty packaging | UV-326 |
| Returnable crates | UV-326 |
| TPE - generic | UV-326 |
| Plastic containers | UV-329, UV-P |
| Plastic coffee cups | UV-P |
| Sports bottles | UV-P |

**Renewable energy**

Table A-13: Uses identified through literature searches and stakeholder engagement for the renewable energy sector.

| Use | Substance |
|---|---|
| Solar panels | UV-234 |
| Rotor coating | UV-234 |

**Sports equipment**

Table A-14: Uses identified through literature searches and stakeholder engagement for the sports equipment sector.

| Use | Substance |
|---|---|
| Helmets | UV-234 |
| Paddles | UV-234 |
| Playground equipment | UV-234 |
| Artificial turf | UV-326 |
| TPE - generic | UV-326 |

### Textiles and fibres

Table A-15: Uses identified through literature searches and stakeholder engagement for the textiles and fibres sector.

| Use | Substance |
|---|---|
| Automotive fibres - generic | UV-234 |
| Building and construction applications - generic | UV-234 |
| Carpet and upholstery - generic | UV-234 |
| PVC shoes or sole | UV-326 |
| PVC leather | UV-326 |
| Textiles dyes - generic | UV-326 |
| Polyester and Spandex fibre | UV-P |
| Textiles - generic | UV-P |

### Wire and cable

Table A-16: Uses identified through literature searches and stakeholder engagement for the wire and cable sector.

| Use | Substance |
|---|---|
| Elastomers for jackets (electronics) | UV-234, UV-329 |
| Optical fibres and cables | UV-234 |
| Outdoor cables | UV-234 |
| Charging cables | UV-234 |
| Wires - generic | UV-234, UV-326 |
| TPU for jackets | UV-326 |
| TPE - generic | UV-326 |

# Appendix 3 Detailed Emissions Estimates

The following Tables (Table A-17 – Table A-20) contain the raw data outputs for the baseline emissions analysis for all four UV-light stabilisers, calculated according to the methods outlined in Appendix 1. The figures represent the annual emissions, in tonnes, to each receiving compartment.

Table A-17: Detailed baseline emissions analysis for UV-326, covering emissions to air and water, for all tonnage scenarios and sectors, in tonnes per year.

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Receiving compartment | | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y |
| Adhesives and sealants | Low | 0.0044 | 0.0262 | 0.0112 | 0.0656 | 0.02 | 0.131 | 0.0336 | 0.196 | 0.0448 | 0.2625 |
| | Central | 0.04485 | 0.2625 | 0.112 | 0.656 | 0.224 | 1.3125 | 0.336 | 1.96 | 0.448 | 2.625 |
| | Upper | 0.0852 | 0.498 | 0.213 | 1.246 | 0.426 | 2.49 | 0.639 | 3.74 | 0.852 | 4.988 |
| Building and construction | Low | 0.003 | 0.003 | 0.007 | 0.007 | 0.015 | 0.015 | 0.022 | 0.022 | 0.03 | 0.03 |
| | Central | 0.0045 | 0.0045 | 0.011 | 0.011 | 0.0225 | 0.0225 | 0.033 | 0.033 | 0.045 | 0.045 |
| | Upper | 0.0058 | 0.0058 | 0.0146 | 0.0146 | 0.0292 | 0.0292 | 0.0438 | 0.0438 | 0.058 | 0.058 |
| Coatings, paints and inks | Low | 0.00331 | 0.0258 | 0.0082 | 0.0646 | 0.0166 | 0.129 | 0.0249 | 0.194 | 0.0331 | 0.258 |
| | Central | 0.0331 | 0.258 | 0.0828 | 0.646 | 0.165 | 1.291 | 0.249 | 1.938 | 0.331 | 2.58 |
| | Upper | 0.063 | 0.491 | 0.15 | 1.227 | 0.315 | 2.454 | 0.472 | 3.681 | 0.630 | 4.908 |
| Electronics | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.002 | 0.002 | 0.005 | 0.005 | 0.01 | 0.01 | 0.015 | 0.015 | 0.02 | 0.02 |
| | Upper | 0.0057 | 0.0057 | 0.014 | 0.014 | 0.0285 | 0.0285 | 0.0427 | 0.0427 | 0.057 | 0.057 |
| Mobility and automotive | Low | 0.00018 | 0.00018 | 0.00045 | 0.00045 | 0.0009 | 0.0009 | 0.00135 | 0.00135 | 0.0018 | 0.0018 |
| | Central | 0.0018 | 0.0018 | 0.0045 | 0.0045 | 0.009 | 0.009 | 0.0135 | 0.0135 | 0.018 | 0.018 |
| | Upper | 0.00342 | 0.00342 | 0.00855 | 0.00855 | 0.0171 | 0.0171 | 0.0256 | 0.0256 | 0.0342 | 0.0342 |
| Packaging | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.0047 | 0.0047 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |
| Renewable energy | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Textiles and fibres | Low | 0.0005 | 0.0005 | 0.00125 | 0.00125 | 0.0025 | 0.0025 | 0.00375 | 0.00375 | 0.005 | 0.005 |
| | Central | 0.005 | 0.005 | 0.0125 | 0.0125 | 0.025 | 0.025 | 0.0375 | 0.0375 | 0.05 | 0.05 |
| | Upper | 0.0095 | 0.0095 | 0.02375 | 0.02375 | 0.0475 | 0.0475 | 0.071 | 0.071 | 0.095 | 0.095 |
| Sports equipment | Low | 0.0003 | 0.0003 | 0.00075 | 0.00075 | 0.0015 | 0.0015 | 0.00225 | 0.00225 | 0.003 | 0.003 |
| | Central | 0.003 | 0.003 | 0.0075 | 0.0075 | 0.015 | 0.015 | 0.0225 | 0.0225 | 0.03 | 0.03 |
| | Upper | 0.0057 | 0.0057 | 0.0142 | 0.0142 | 0.0285 | 0.0285 | 0.0427 | 0.0427 | 0.057 | 0.057 |
| Wire and cable | Low | 0.00023 | 0.00023 | 0.00057 | 0.00057 | 0.0011 | 0.00115 | 0.0017 | 0.0017 | 0.0023 | 0.0023 |
| | Central | 0.0023 | 0.0023 | 0.0057 | 0.0057 | 0.0115 | 0.0115 | 0.0173 | 0.0173 | 0.0231 | 0.0231 |
| | Upper | 0.0043 | 0.0043 | 0.0109 | 0.0109 | 0.0219 | 0.0219 | 0.0329 | 0.0329 | 0.043 | 0.043 |

Table A-18: Detailed baseline emissions analysis for UV-329, covering emissions to air and water, for all tonnage scenarios and sectors, in tonnes per year.

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Receiving compartment | | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y |
| Adhesives and sealants | Low | 0.0044 | 0.0262 | 0.0112 | 0.0656 | 0.02 | 0.131 | 0.0336 | 0.196 | 0.0448 | 0.2625 |
| | Central | 0.04485 | 0.2625 | 0.112 | 0.656 | 0.224 | 1.3125 | 0.336 | 1.96 | 0.448 | 2.625 |
| | Upper | 0.0852 | 0.498 | 0.213 | 1.246 | 0.426 | 2.49 | 0.639 | 3.74 | 0.852 | 4.988 |
| Building and construction | Low | 0.0028 | 0.0028 | 0.007 | 0.007 | 0.014 | 0.014 | 0.021 | 0.021 | 0.028 | 0.028 |
| | Central | 0.0042 | 0.0042 | 0.0105 | 0.0105 | 0.021 | 0.021 | 0.0315 | 0.0315 | 0.042 | 0.042 |
| | Upper | 0.00546 | 0.00546 | 0.01365 | 0.01365 | 0.0273 | 0.0273 | 0.04095 | 0.04095 | 0.0546 | 0.0546 |
| Coatings, paints and inks | Low | 0.00331 | 0.0258 | 0.0082 | 0.0646 | 0.0166 | 0.129 | 0.0249 | 0.194 | 0.0331 | 0.258 |
| | Central | 0.0331 | 0.258 | 0.0828 | 0.646 | 0.165 | 1.291 | 0.249 | 1.938 | 0.331 | 2.58 |
| | Upper | 0.063 | 0.491 | 0.15 | 1.227 | 0.315 | 2.454 | 0.472 | 3.681 | 0.630 | 4.908 |

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Electronics | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.00475 | 0.00475 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |
| Mobility and automotive | Low | 0.0036 | 0.0036 | 0.009 | 0.009 | 0.018 | 0.018 | 0.027 | 0.027 | 0.036 | 0.036 |
| | Central | 0.0054 | 0.0054 | 0.0135 | 0.0135 | 0.027 | 0.027 | 0.0405 | 0.0405 | 0.054 | 0.054 |
| | Upper | 0.00702 | 0.00702 | 0.017 | 0.017 | 0.0351 | 0.0351 | 0.052 | 0.052 | 0.070 | 0.070 |
| Packaging | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.00475 | 0.00475 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |
| Renewable energy | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Textiles and fibres | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sports equipment | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wire and cable | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.00475 | 0.00475 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |

Table A-19: Detailed baseline emissions analysis for UV-234, covering emissions to air and water, for all tonnage scenarios and sectors, in tonnes per year.

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Receiving compartment | | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y |
| Adhesives and sealants | Low | 0.0044 | 0.0262 | 0.0112 | 0.0656 | 0.02 | 0.131 | 0.0336 | 0.196 | 0.0448 | 0.2625 |
| | Central | 0.04485 | 0.2625 | 0.112 | 0.656 | 0.224 | 1.3125 | 0.336 | 1.96 | 0.448 | 2.625 |
| | Upper | 0.0852 | 0.498 | 0.213 | 1.246 | 0.426 | 2.49 | 0.639 | 3.74 | 0.852 | 4.988 |
| Building and construction | Low | 0.002 | 0.002 | 0.005 | 0.005 | 0.01 | 0.01 | 0.015 | 0.015 | 0.02 | 0.02 |
| | Central | 0.003 | 0.003 | 0.0075 | 0.0075 | 0.015 | 0.015 | 0.0225 | 0.0225 | 0.03 | 0.03 |
| | Upper | 0.0039 | 0.0039 | 0.00975 | 0.00975 | 0.0195 | 0.0195 | 0.02925 | 0.02925 | 0.039 | 0.039 |
| Coatings, paints and inks | Low | 0.00331 | 0.0258 | 0.0082 | 0.0646 | 0.0166 | 0.129 | 0.0249 | 0.194 | 0.0331 | 0.258 |
| | Central | 0.0331 | 0.258 | 0.0828 | 0.646 | 0.165 | 1.291 | 0.249 | 1.938 | 0.331 | 2.58 |
| | Upper | 0.063 | 0.491 | 0.15 | 1.227 | 0.315 | 2.454 | 0.472 | 3.681 | 0.630 | 4.908 |
| Electronics | Low | 0.00014 | 0.00014 | 0.00035 | 0.00035 | 0.0007 | 0.0007 | 0.00105 | 0.00105 | 0.0014 | 0.0014 |
| | Central | 0.0014 | 0.0014 | 0.0035 | 0.0035 | 0.007 | 0.007 | 0.0105 | 0.0105 | 0.014 | 0.014 |
| | Upper | 0.0026 | 0.0026 | 0.0066 | 0.0066 | 0.0133 | 0.0133 | 0.0199 | 0.0199 | 0.0266 | 0.0266 |
| Mobility and automotive | Low | 0.0028 | 0.0028 | 0.007 | 0.007 | 0.014 | 0.014 | 0.021 | 0.021 | 0.028 | 0.028 |
| | Central | 0.0042 | 0.0042 | 0.0105 | 0.0105 | 0.021 | 0.021 | 0.0315 | 0.0315 | 0.042 | 0.042 |
| | Upper | 0.0054 | 0.0054 | 0.0136 | 0.0136 | 0.0273 | 0.0273 | 0.0409 | 0.0409 | 0.054 | 0.054 |
| Packaging | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.00475 | 0.00475 | 0.0095 | 0.0095 | 0.0142 | 0.0142 | 0.019 | 0.019 |
| Renewable energy | Low | 0.0005 | 0.0005 | 0.00125 | 0.00125 | 0.0025 | 0.0025 | 0.00375 | 0.00375 | 0.005 | 0.005 |
| | Central | 0.005 | 0.005 | 0.0125 | 0.0125 | 0.025 | 0.025 | 0.0375 | 0.0375 | 0.05 | 0.05 |
| | Upper | 0.0095 | 0.0095 | 0.0237 | 0.023 | 0.047 | 0.047 | 0.0712 | 0.0712 | 0.095 | 0.095 |

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Textiles and fibres | Low | 0.0003 | 0.0003 | 0.00075 | 0.00075 | 0.0015 | 0.0015 | 0.0022 | 0.0022 | 0.003 | 0.003 |
| | Central | 0.003 | 0.003 | 0.0075 | 0.0075 | 0.015 | 0.015 | 0.0225 | 0.0225 | 0.03 | 0.03 |
| | Upper | 0.0057 | 0.0057 | 0.014 | 0.014 | 0.0285 | 0.0285 | 0.0427 | 0.0427 | 0.057 | 0.057 |
| Sports equipment | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.00475 | 0.00475 | 0.0095 | 0.0095 | 0.0142 | 0.014 | 0.019 | 0.019 |
| Wire and cable | Low | 0.00025 | 0.00025 | 0.000625 | 0.000625 | 0.00125 | 0.00125 | 0.001875 | 0.001875 | 0.0025 | 0.0025 |
| | Central | 0.0025 | 0.0025 | 0.00625 | 0.00625 | 0.0125 | 0.0125 | 0.0187 | 0.0187 | 0.025 | 0.025 |
| | Upper | 0.00475 | 0.00475 | 0.0118 | 0.0118 | 0.0237 | 0.0237 | 0.0356 | 0.0356 | 0.0475 | 0.0475 |

Table A-20: Detailed baseline emissions analysis for UV-P, covering emissions to air and water, for all tonnage scenarios and sectors, in tonnes per year.

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Receiving compartment | | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y | Air t/y | Water t/y |
| Adhesives and sealants | Low | 0.0044 | 0.0262 | 0.0112 | 0.0656 | 0.02 | 0.131 | 0.0336 | 0.196 | 0.0448 | 0.2625 |
| | Central | 0.04485 | 0.2625 | 0.112 | 0.656 | 0.224 | 1.3125 | 0.336 | 1.96 | 0.448 | 2.625 |
| | Upper | 0.0852 | 0.498 | 0.213 | 1.246 | 0.426 | 2.49 | 0.639 | 3.74 | 0.852 | 4.988 |
| Building and construction | Low | 0.0036 | 0.0036 | 0.009 | 0.009 | 0.018 | 0.018 | 0.027 | 0.027 | 0.036 | 0.036 |
| | Central | 0.0054 | 0.0054 | 0.0135 | 0.0135 | 0.027 | 0.027 | 0.0405 | 0.0405 | 0.054 | 0.054 |
| | Upper | 0.00702 | 0.00702 | 0.017 | 0.017 | 0.0351 | 0.0351 | 0.0527 | 0.0527 | 0.0702 | 0.0702 |
| Coatings, paints and inks | Low | 0.00331 | 0.0258 | 0.0082 | 0.0646 | 0.0166 | 0.129 | 0.0249 | 0.194 | 0.0331 | 0.258 |
| | Central | 0.0331 | 0.258 | 0.0828 | 0.646 | 0.165 | 1.291 | 0.249 | 1.938 | 0.331 | 2.58 |

| Sector | | 1,000 tonnes | | 2,500 tonnes | | 5,000 tonnes | | 7,500 tonnes | | 10,000 tonnes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper | 0.063 | 0.491 | 0.15 | 1.227 | 0.315 | 2.454 | 0.472 | 3.681 | 0.630 | 4.908 |
| Electronics | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.0048 | 0.0048 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |
| Mobility and automotive | Low | 0.00012 | 0.00012 | 0.0003 | 0.0003 | 0.0006 | 0.0006 | 0.0009 | 0.0009 | 0.0012 | 0.0012 |
| | Central | 0.0012 | 0.0012 | 0.003 | 0.003 | 0.006 | 0.006 | 0.009 | 0.009 | 0.012 | 0.012 |
| | Upper | 0.0022 | 0.0022 | 0.0057 | 0.0057 | 0.011 | 0.011 | 0.017 | 0.017 | 0.023 | 0.023 |
| Packaging | Low | 0.0001 | 0.0001 | 0.00025 | 0.00025 | 0.0005 | 0.0005 | 0.00075 | 0.00075 | 0.001 | 0.001 |
| | Central | 0.001 | 0.001 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.0075 | 0.0075 | 0.01 | 0.01 |
| | Upper | 0.0019 | 0.0019 | 0.0048 | 0.0048 | 0.0095 | 0.0095 | 0.014 | 0.014 | 0.019 | 0.019 |
| Renewable energy | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Textiles and fibres | Low | 0.0004 | 0.0004 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 | 0.003 | 0.004 | 0.004 |
| | Central | 0.004 | 0.004 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.04 |
| | Upper | 0.008 | 0.008 | 0.019 | 0.019 | 0.038 | 0.038 | 0.057 | 0.057 | 0.076 | 0.076 |
| Sports equipment | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wire and cable | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Central | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Upper | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Appendix 4 Physico-chemical properties of UV-light stabilisers

Table A-21: Physico-chemical properties of UV-326, UV-329, UV-234 and UV-P.

| Substance | CAS | EC | Molecular weight | pKa | LogKow | LogKoc | Koc | Vapour pressure (Pa) at 25°C | Water solubility (mg $L^{-1}$) | Melting point | Boiling point |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UV-326 | 3896-11-5 | 223-445-4 | 316 | 10 at 25 °C | 5.4 at 25°C | 4.235 | 17,170 L/kg at 25 °C | 0.000000075 | 0.004 at 20 °C | 138 – 141 °C | 460±55.0 °C (predicted) |
| UV-329 | 3147-75-9 | 221-573-5 | 323 | 8.9 at 25 °C | 7.4 at 25°C | 4.926 at 25 °C | 84,360 L/kg at 25 °C | 0.000147 at 20 °C | 0.173 at 20 °C | 101-106 °C | 471.8 ± 55.0 °C (Predicted) |
| UV-234 | 70321-86-7 | 274-570-6 | 448 | | 6.5 at 23 °C | 7.79 at 25°C | | <0.0001 | <0.005 at 25°C | 139.2 °C | N/A |
| UV-P | 2440-22-4 | 219-470-5 | 225 | 8.2 at 25 °C | 4.2 at 25°C | | 5190 at 20 °C | 0.000147 at 20 °C | 0.173 at °C | 128-132°C | 225 °C |

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