Guidance on best available techniques and best environmental practices relevant to UV-328 listed under the Stockholm Convention on Persistent Organic Pollutants

January 2025

Acknowledgements

The work to review and update the guidelines and guidance on best available techniques and best environmental practices is conducted by the experts on best available techniques and best environmental practices in accordance with the terms of reference set out in annex to decision SC-8/6, through the in-kind contributions of the nominated experts. The valuable input of the experts nominated by Parties and observers to be consulted in the process for review and update of the guidelines and guidance is highly acknowledged. The experts' names are listed in the joint Toolkit and Best Available Techniques and Best Available Practices expert roster, accessible on the Stockholm Convention's website (https://chm.pops.int/tabid/9650).

Table of Contents

Abbreviations and acronyms

BAT	Best available techniques
BEP	Best environmental practices
CEMS	Continuous emission monitoring systems
EIA	Environmental impact assessments
EMS	Environmental Management System
GC-MS	Gas chromatography-mass spectrometry
HALS	Hindered amine light stabilizers
HEPA	High-efficiency particulate air
JRC	Joint Research Centre
LCA	Life cycle assessment
LCD	Liquid crystal devices
LCM	Life cycle management
LC-MS	Liquid chromatography-mass spectrometry
LEV	Local Exhaust Ventilation
OECD	Organization for Economic Co-operation and Development
PC	Polycarbonate
PET	Polyethylene terephthalate
POPs	Persistent organic pollutants
POPRC	Persistent Organic Pollutants Review Committee
PP	Polypropylene
PPE	Personal Protective Equipment
PS	Polystyrene
PVC	Polyvinyl chloride
REACH	European Union regulation on the Registration, Evaluation, Authorization and Restriction of Chemicals
SPE	Solid-phase extraction
SPIN	the Substances in Products in the Nordic Countries
SVHC	Substances of very high concern
TAC	Triacetyl cellulose
TPE	Thermoplastic elastomer
UV	Ultraviolet
UV-234	2-(2H-Benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol
UV-326	2-tert-butyl-6-(5-chloro-2H-benzotriazol-2-yl)-4-methylphenol
UV-328	2-(2H-Benzotriazol-2-yl)-4,6-bis(2-methylbutan-2-yl)phenol
UV-329	2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol
UV-360	2-2’-Methylenebis[6-(2H-benzotriazol-yl)-4-(1,1,3,3-tetrametyhlbutyl)phenol
UV-571	2-(2H-benzotriazol-2-yl)-6-dodecyl-4-methylphenol
UV-928	2-(2H-Benzotriazol-2-yl)-6-(1-methyl-1-phenylethyl)-4-(1,1,3,3-tetramethylbutyl)phenol
UV-P	2-(2H-benzotriazol-2-yl-p-cresol
VOC	Volatile organic compound

Units

t/a	Tonnes per annum
g/mol	Grams per mole
μg/g	micrograms per gram

Executive Summary

UV-328 is a phenolic benzotriazole used as an ultraviolet (UV) absorber to protect various surfaces from discoloration and weathering. UV-328 has been listed in Annex A to the Stockholm Convention on Persistent Organic Pollutants in 2023 with specific exemptions.

UV-328 is likely produced in large quantities globally, with a production volume exceeding 1,000 tonnes per annum. It is used extensively in various applications, being its main use in paints and coatings, and as an additive in a wide variety of plastics.

The aim of this document is to provide guidance on best available techniques (BAT) and best environmental practices (BEP) for production of UV-328 and specific exemptions for uses of UV-328, including its use in automotive parts, industrial coatings, blood collection tubes, polarizers, photographic paper, and other industrial machinery. These measures aim to minimize the environmental impact of UV-328 through strategies such as material substitution, waste reduction, recycling, and pollution control technologies. To date, however, no detailed information on practices that would be considered as BAT or BEP for the production and exempted uses of this persistent organic pollutant could be identified.

UV-328 waste should be managed in an environmentally sound manner in accordance with Article 6 of the Stockholm Convention and the Basel Convention on the control of the movements of hazardous wastes and their disposal general and specific technical guidelines. Reuse and recycling of POPs-containing wastes and stockpiles is not allowed under the Stockholm Convention, unless specified through an exemption. The destruction or irreversible transformation of the UV-328, waste generated from UV-328 production and from parts and coatings where UV-328 has been added and avoiding its recovery, recycling, reclamation, direct reuse or alternative uses is seen as the most efficient way to ensure no further spread or emission of the substance.

Alternative UV absorbers are available, i.e., other phenolic benzotriazoles, benzophenones, hindered amine light stabilizers (HALS), oxalanilides and cyanoacrylates. However, to date, no detailed information could be identified which exact alternative might serve as a suitable alternative for the exempted uses of UV-328. Furthermore, information on specific uses, where non-chemical alternatives are available, could not be identified. This is supported by industry feedback, which suggests that the alternative substances represent viable alternatives to UV-328. Depending on the specific requirements of the final plastic application, alternative chemistries indicated above are available to stabilize plastics. However, each UV absorber has its specific substance properties and several substitutes to UV-328 could be as harmful as UV-328. This applies in particular to the substitution with other phenolic benzotriazoles, which were added to the European Union's Authorisation List or which are under persistent, bioaccumulative and toxic (PBT) assessment, but also to other potential alternatives such as benzophenones. Therefore, the selection of a replacement candidate for UV-328 must be carefully evaluated to ensure the product's performance is not compromised and to avoid regrettable substitution, with a priority on pursuing safer alternatives.

1. Introduction

In May 2020, Switzerland submitted a proposal to list UV-328 in Annex A to the Stockholm Convention. The proposal was submitted in accordance with Article 8 of the Convention, and was reviewed by the Persistent Organic Pollutants Review Committee (POPRC) at its sixteenth meeting held in January 2021 where the Committee concluded that UV- 328 fulfilled the screening criteria set out in Annex D to the Convention and decided that a risk profile of the chemical be prepared by an intersessional working group (decision POPRC-16/3).

In January 2022, at the seventeenth meeting of the POPRC, the Committee adopted the risk profile for UV-328 and decided that UV-328 is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and/or environmental effects such that global action is warranted (POPRC-17/3). An intersessional working group was established to prepare a risk management evaluation that included an analysis of possible control measures for UV-328 in accordance with Annex F to the Convention (POPRC-17/3).

At the eighteenth meeting of the POPRC in September 2022, the Committee adopted the risk management evaluation for UV-328 and decided, in accordance with paragraph 9 of Article 8 of the Convention, to recommend to the Conference of the Parties that it consider listing UV-328 in Annex A to the Convention with specific exemptions (Decision POPRC-18/2).

At its eleventh meeting in May 2023, after considering the risk profile and the risk management evaluation for UV-328 as transmitted by the POPRC and taking note of the recommendation by the Committee, by its Decision SC-11/11, the Conference of the Parties adopted a decision amending Annex A to the Stockholm Convention on Persistent Organic Pollutants to list UV-328 with specific exemptions (Decision SC-11/11).

1.1. Purpose

The concept of BAT is not aimed at the prescription of any specific technique or technology. BAT means the most effective and advanced activities, methods of operation, and techniques for providing the basis for release limitations designed to prevent and, generally to reduce releases of chemicals and their impact on the environment. BEP describes the application of the most appropriate combination of environmental control measures and strategies (Article 5, f (i) and (v) of the Stockholm Convention on POPs).

Article 3, paragraph 6 of the Stockholm Convention requests Parties that have a specific exemption and/or acceptable purpose for a chemical listed in Annex A or Annex B to the Convention to take measures to ensure that any production or use under such exemption or purpose is carried out in a manner that prevents or minimizes human exposure and releases to the environment (e.g., applying BAT and BEP).

This document has been developed to provide guidance for Parties in their actions to prevent or reduce releases of UV-328 from production and use under the specific exemptions and acceptable purposes listed in the Convention at its eleventh meeting in 2023 (SC-11/11).

1.2. Structure and use of the guidance

Chapter 1 outlines the purpose and structure of this document and provides an overview of the chemical identity of UV-328.

Chapter 2 provides an overview of the production and uses of UV-328.

Chapter 3 provides specific BAT and BEP guidance for the management of UV-328 for the applications listed as a specific exemption under the Convention.

Chapter 4 addresses general BAT and BEP principles for general chemical management and general guidance for the management of UV-328.

1.3. Listing of UV-328 in the Stockholm Convention

UV-328 is a phenolic benzotriazole that is substituted with two tert-pentyl groups at the fourth and sixth position of its phenolic moiety. UV-328 absorbs the full spectrum of UV light in a fully reversible and non-destructive process (ECHA, 2014). It is therefore used as a UV absorber to protect various surfaces against discoloration and weathering under UV/sunlight. Table 1 shows the various chemical identifiers and registration numbers of UV-328. Table 2 shows the molecular characteristics of UV-328, which can exist in both open and closed forms.

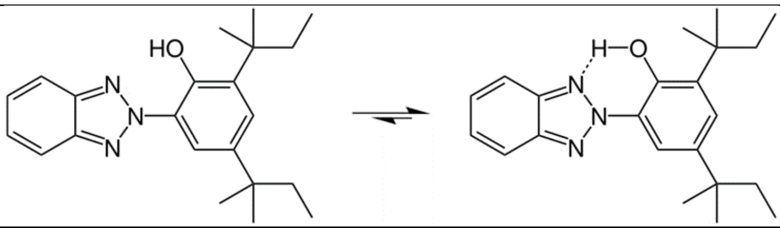
UV-328 is highly hydrophobic, adsorbs and/or absorbs strongly to organic material, and has a low tendency to volatilize. When released into water, it will likely partition to particles and organic matter, suspended or deposited (ECHA, 2014).

UV-328 is a substance that does not occur naturally in the environment, but has been detected in various environmental compartments, biota and humans all over the world. It is considered to be persistent and bioaccumulative, with significant adverse human health and/or environmental effects (UNEP/POPS/POPRC.17/13/Add.3).

Table 1. Names, including a most likely non-exhaustive list of commercial names, and Chemical Abstract (CAS) and European Community (EC) numbers of UV-328.

Common name	UV-328
IUPAC name	2-(2H-Benzotriazol-2-yl)-4,6-bis(2-methylbutan-2-yl)phenol
CAS name	Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylpropyl)-
Synonym	2-(2H-Benzotriazol-2-yl)-4,6-di-tert-pentylphenol (BDTP), 2-(2′-Hydroxy-3′,5′-di-t-amylphenyl) benzotriazole
Commercial names	BLS 1328, Chiguard 328, Chisorb 328, Cyasorb UV 2337, Eversorb 74, GSTAB 328, Hostavin 3310 P, Kemisorb 74, Lowilite 28, Milestab 328, Seesorb 704, Songsorb 3280, Sumisorb 350, Thasorb UV328, Tin 328, Tinuvin 328, UV 2337, UV 74, Uvinul 3028, Viosorb 591
CAS number	25973-55-1
EC number	247-384-8

Table 2. Molecular characteristics of UV-328.

Molecular formula	$C_{22}H_{29}N_3O$
Molecular weight	351.5 g/mol
Substance type	Mono-constituent
Degree of purity	⩾ 80–100% by weight
Structural formulas (left: open form; right: closed form)	

2. Production and use

2.1. Background

The earliest known production of UV-328 began in 1970 (Jungclaus et al. 1978). No time trends are publicly available regarding the global production of UV-328 since production began. On a global scale, UV-328 is used in large quantities (NICNAS, 2017). According to the Organization for Economic Co-operation and Development (OECD) Existing Chemicals Database, UV-328 is designated as a high production volume chemical, with production > 1000 tonnes per annum (t/a) (UNEP/POPS/POPRC.17/4). Worldwide, there were 77 suppliers identified of UV-328 (ECHA, 2020).

In the European Union (EU), UV-328 is registered under the tonnage band of 100–1000 t/a (ECHA, 2022b). One registrant and one co-registrant of UV-328 stated that 100 % of the substance is imported into the EU and placed on the market as a pure substance or in mixtures (ECHA, 2020). Thereof, the majority is imported from Asia (ECHA, 2020). The substance is manufactured and/or imported by 11 registrants with companies being located in Belgium, Germany, Netherlands and Italy (Annex F, EU, 2022). Feedback from manufacturers suggests a complex supply chain. Accordingly, manufacturers mainly provide masterbatches containing UV-328 to converters for further processing. The converters supply plastics to producers who deliver final plastic products to the end users (ECHA, 2020). There are 9 European suppliers of UV-328 (ECHA, 2020).

There are three REACH registrants for UV-328 based in the Netherlands and located in Capelle a/d IIssel, Mijdrecht and Uithoorn (Annex F, Netherlands, 2022). It is unknown whether these registrants produce in the Netherlands, but the information provided in ECHA (2020) suggest that they only import.

In Hungary, 21 companies use UV-328 at < 1 t/a/company (Annex E, 2021).

In Monaco, UV-328 is not produced nor used (Annex F, Monaco, 2022).

According to the Annex F submission of Norway (2022), UV-328 is not produced in Norway. The imported sum of UV-327, UV-328, UV-320 and UV-350 registered in the Norwegian Products Register declined from 1.9 t in 2009 to 0.17 t in 2019.

In the United Kingdom of Great Britain and Northern Ireland (UK), there is one registrant of UV-328, which comes under the tonnage band of 100–1,000 t/a. As this registrant held an EU REACH registration, it is assumed that the registrant is an importer rather than a UK based producer of UV-328 (Annex F, UK, 2022).

According to a report by Environment and Climate Change Canada (ECCC) and Health Canada (2016), UV-328 is not manufactured in Canada. In 2000, total import of UV-328 was in the range of 100 to 1,000 t. In the years 2012 and 2013, total Canadian import of UV-328 was significantly lower (i.e., in the range of 10 to 100 t per year, excluding quantities in finished articles, for which no information is available).

In the United States of America, the annual production volume ranged between 450 to 4,500 t from 1986 to 2006 (US EPA, 2011, as cited in ECCC and Health Canada, 2016). Between 2011 and 2015 the reported national aggregate production volume was in the same range (450–4,500 t/a) (US EPA, 2018, 2020). The production volume includes domestically manufactured and imported volumes of UV-328. Of 11 companies and company sites for which data on the production volume is available, only one company/company site reported that UV-328 is manufactured domestically. The remaining companies/company sites reported that the substance was imported (8 companies/company sites) or claimed the data as Confidential Business Information (2 companies/company sites) (US EPA, 2018).

In Russia, UV-328 is not produced. In Belarus, UV-328 has never been produced (Annex F, Republic of Belarus, 2022).

In Japan, the annual production and usage volume of UV-328 is currently below 1,000 t (Annex F, Japan, 2022).

Based on information gathered from the 'Statistical Survey for Chemicals' under the Chemical Control Act, 0.25 t of UV-328 were produced in the Republic of Korea in 2018 (Annex F, Republic of Korea, 2022).

In summary, UV-328 is likely produced in large quantities worldwide with a likely global production volume > 1,000 t/a. No time trends are publicly available for global production. Data on specific production volumes at the national level is only available to a limited extent. Data indicate that most of the countries for which data is available mainly import UV-328 instead of producing it domestically.

In June 2023, by decision SC-11/11, the Conference of the Parties to the Stockholm Convention amended Annex A to the Convention to list UV-328. The listing includes specific exemptions for production as allowed for the Parties listed in the register of specific exemptions and for use in accordance with the provisions of Part XII of Annex A as follows:

Chemical	Activity	Specific exemptions
UV-328 CAS No 25973-55-1	Production	As allowed for the Parties listed in the Register of Specific Exemptions in accordance with the provisions of Part XII of Annex A
	Use	In accordance with the provisions of Part XII of Annex A • Parts of motor vehicles (covering all land-based vehicles, such as cars, motorcycles, agricultural and construction vehicles and industrial trucks), such as bumper systems, radiator grills, spoilers, car garnish, roof modules, soft/hard tops, trunk lids and rear window wipers • Industrial coating applications for motor vehicles, engineering machines, rail transportation vehicles, and heavy-duty coatings for large steel structures • Mechanical separators in blood collection tubes • Triacetyl cellulose (TAC) film in polarizers • Photographic paper • Replacement parts for articles in applications in accordance with the provisions of paragraphs 2 and 3 of part XII of Annex A

A new part XII of Annex A sets further provisions for the production and use of UV-328, as follows:

1. The production and use of UV-328 shall be eliminated except for Parties that have notified the Secretariat of their intention to produce and/or use it in accordance with Article 4.

2. Specific exemptions for the production and use of UV-328 for replacement parts for articles shall apply where UV-328 was originally used in the manufacture of those articles and may be available, limited to the following applications, until the end of the service life of the articles or 2044, whichever comes earlier:

(a) Motor vehicles (covering all land-based vehicles, such as cars, motorcycles, agricultural and construction vehicles and industrial trucks);

(b) Stationary industrial machines (such as tower cranes, concrete plants and hydraulic crushers) for use in agriculture, forestry and construction;

(c) Liquid crystal displays in instruments for analysis, measurements, control, monitoring, testing, production and inspection (such as recorders, infrared radiation thermometers, digital storage oscilloscopes and radiographic testing instruments) other than for medical applications.

3. Specific exemptions for the use of UV-328 for replacement parts for articles for the following applications for medical purposes shall apply where UV-328 was originally used in the manufacture of those articles and may be available until the end of the service life of those articles, subject to review by the Conference of the Parties no later than 2041:

(a) Liquid crystal displays in medical and in-vitro diagnostic devices (such as ultrasound diagnostic devices, flexible endoscopes, immunoassay analysers, clinical chemistry analysers and blood coagulation analysers);

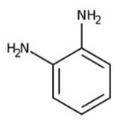
(b) Liquid crystal displays in instruments for analysis, measurements, control, monitoring, testing, production and inspection (such as recorders, infrared radiation thermometers, digital storage oscilloscopes and radiographic testing instruments).

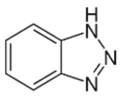
2.2. Production

2.2.1 UV-328 synthesis and industrial manufacturing

The synthesis of UV-328 involves several chemical reactions. Detailed experimental procedures and outcomes are given in resources like BenchChem (BenchChem, n.d.), which provides synthesis routes for various chemicals, including UV-328.

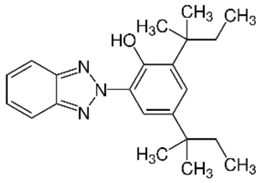
The synthesis of UV-328 (2-(2H-benzotriazol-2-yl)-4-(tert-octyl)phenol) involves several key steps, beginning with the formation of the benzotriazole core, followed by functionalization with phenol and tert-octyl substituents. The specific steps can vary based on the synthesis route, but the general outline is as follows:

(a) Synthesis of Benzotriazole Core:
- Starting Materials: o-Phenylenediamine (an aromatic diamine)  and sodium nitrite ($NaNO_2$).
- Reaction Steps:
    - Diazotization: o-Phenylenediamine is treated with sodium nitrite in acidic conditions, creating a diazonium salt intermediate.
    - Cyclization: The diazonium intermediate cyclizes, resulting in the benzotriazole core:



(b) Preparation of 2-(2H-benzotriazol-2-yl)-phenol Intermediate:
- Step 1: The benzotriazole is further reacted with a phenol compound to form a substituted phenolic derivative.
- Conditions: This reaction generally takes place in the presence of a base to facilitate the attachment of the phenolic group at the 2-position of the benzotriazole ring.

(c) Functionalization with tert-Octyl Group (Alkylation):
- Alkylation step: A tert-octyl group is introduced to the 4-position of the phenolic ring.
- Reagents: A tert-octyl halide (such as tert-octyl chloride or bromide) is commonly used as the alkylating agent, in the presence of a strong base or catalyst.
- Reaction Conditions: The reaction may be carried out under heating conditions to facilitate the substitution.



(UV-328)

(d) Purification: The product is isolated and purified, often through recrystallization or chromatography, to obtain a high-purity UV-328 compound (over 98%).

The industrial manufacturing process for UV-328 does not seem to be well documented. Details provided in this chapter stem from general sources (Furniss et al., 1989; Gérardy & Monbaliu, 2015; Kale et al., 2010; Raval, Baldania & Shah, n.d.) and BenchChem Database (BenchChem, n.d.).

2.2.2 Solvents Used in the Synthesis of UV-328

In the preparation of benzotriazole, solvents play essential roles in the diazotization step, which has to occur in acidic conditions. The choice of solvent depends on factors like reactivity, ability to dissolve reactants, and ease of recovery.

The diazotization and cyclization reactions often occur in an aqueous medium, typically acidified with hydrochloric acid (HCl), sulfuric acid (H_2SO_4), or acetic acid (CH3COOH). These acidic aqueous solutions provide the right conditions for diazotization (formation of diazonium ion) and cyclization.

For purification and recrystallization, organic solvents such as methanol or ethanol are frequently used. These solvents help dissolve impurities while allowing the UV-328 product to crystallize out at 15°C.

Alternative Solvents for purification and recrystallization may be used like Toluene, Acetone, or Dichloromethane (DCM). Acetone might also be used for its miscibility with water and lower boiling point, facilitating easier solvent removal.

2.2.3 Uses of UV-328

UV-328 is used in a variety of applications and products. It is applied as a UV stabilizer in plastic shrink films, outdoor furniture and clear coat automotive finishes, as well as for light stabilization in coatings, acrylonitrile butadiene styrene resin, epoxy resin, fiber resin, polypropylene (PP), rigid and flexible polyvinyl chloride (PVC) and polystyrene (PS) (Bolgar et al., 2016; ECHA, 2020). It is also used in unsaturated polyesters, polyacrylate and polycarbonate (PC) (ECHA, 2020). Additionally, it is used in construction materials, fillers, surface treatments, adhesives, paints/lacquers/varnishes, thinners, paint removers, printing inks, consumer fragrances, cosmetics, fabric/textile/leather products and as inert ingredient in pesticides (ECHA, 2018, 2020; Mikkelsen et al., 2015). UV-328 is furthermore used in cooling liquids in refrigerators, in oil-based electric heaters, hydraulic liquids in automotive suspensions and in lubricants in motor oil and break fluids. Due to it being a UV absorber, it is especially used in outdoor products made from wood and plastic. However, it can also be found in indoor products such as furniture, toys, construction materials, leather products, footwear, paper and cardboard articles, flooring and electronic equipment (Denghel, 2021).

In the EU, suppliers of articles containing UV-328 in a concentration above 0.1% by weight need to submit information on these articles from 5 January 2021 to the SCIP Database (Substances of Very High Concern In articles as such or in complex objects (Products)) established under the Waste Framework Directive. By 1 March 2022 the total number of factsheets (entries) related to UV-328 in the SCIP database was 315,251. According to the data supplied by the companies, UV-328 by itself is mainly used in motor vehicles, including motorcycles, and their components and accessories, including seats ($\geqslant$ 65,720 registered factsheets) followed by components and accessories of optical, photographic, cinematographic, medical, surgical or veterinary's instruments and apparatus, as well as measuring instruments and apparatus; including liquid crystal devices, sheets and plates of polarizing material, oxygen therapy, aerosol therapy, artificial respiration or other therapeutic respiration apparatus and other breathing appliances (⩾ 4,993), electrical machinery and equipment (including accessories and parts) including sound recorders and reproducers, television image, including liquid crystal devices (LCD) modules and indicator panels incorporating LCD or light-emitting diodes (≥ 1,826), plastics and plastic articles, including self-adhesive plates, sheets, film, foil, tape, strip and other flat shapes, of plastics, whether or not in rolls (≥ 1,570) and other products (≥ 645). In mixtures that are incorporated in motor vehicles, including motorcycles, and their components and accessories, UV-328 is mainly used in adhesives and sealants (≥ 53,536) and paints and coatings (≥ 47,131) but also in fiber, leather, rubber and polymerized materials preservatives (≥ 875) and in gypsum (≥ 620). In addition, suppliers of articles have notified to SCIP UV-328 as being present in the following materials in articles: Plastic (and polymers), e.g., polyurethanes, poly(methyl methacrylate), polycarbonates, including copolymers, soft polyvinylchloride, (co)polymers of olefins, other acrylic (co)polymers, rubber and elastomers and other (Annex F, EU, 2022).

According to information provided in the United States Environmental Protection Agency (US EPA) ChemView database, UV-328 is mainly used for industrial purposes in the US. Eight out of nine companies/company sites for which data is available indicate that UV-328 is used for industrial purposes, while commercial use (three companies/company sites) and consumer use (one company/company site) is less relevant (US EPA, 2018). Industrial use of UV-328 includes its use as UV absorber, light stabilizer, antioxidant, paint additive and coating additive, photosensitive chemical or adsorbent and absorbent (US EPA, 2018). Commercial and consumer use includes the use in paints and coatings as well as adhesives and sealants (US EPA, 2018).

Based on the Substances in Products in the Nordic Countries (SPIN) database, the product or use categories of UV-328 in 2019 included adhesives and binding agents (3.3 t/a in Finland and 0.1 t/a in Denmark), paints lacquers and varnishes (0.2 t/a in Finland and 0.1 t/a in Norway) and construction materials (0.1 t/a in Norway) (SPIN, 2022). Thus, in these Nordic countries, UV-328 was mainly used for adhesives and binding agents in 2019. In Norway, UV-328 is mainly used in paints and varnishes, but also in rubber and transparent plastics (Annex E, 2021). In Sweden, UV-328 is mainly used as an additive in plastics, paints and sealants (Annex E, 2021).

In Australia, UV-328 is used in industrial sealants in aftermarket automotive products (NICNAS, 2017). In Canada, 63% of UV-328 was used in the plastics sector and 37% in paints and coatings in 1986; and more recently UV-328 is used in automotive paints and coatings, to a minor degree as a sealant in the manufacture of automobiles, and as an additive in plastic food packaging in the non-food contact layer (ECCC and Health Canada, 2016). In Russia, UV-328 is mainly used as a corrosion inhibitor (anti-corrosion agent), in polishes for metal surfaces, as well as for the gravimetric determination of metals such as copper, silver and zinc (Annex E, 2021).

According to a global chemicals manufacturer, approximately 50% of their products containing UV-328 are used as UV-protection agents in coatings, especially for cars and special industrial wood coatings. Approximately 40% are used as UV protection agents for plastics, rubber, and polyurethanes. It is for example used in roof lights and PVC membranes. The rest is used in cosmetics (e.g., as sun protection agents) (Germany, 2014).

In various jurisdictions, UV-328 is used as an additive in the non-food-contact layer of food contact articles. According to the FACET (Flavors, Additives, and Food Contact materials Exposure Task) tool of the European Commission's Joint Research Centre (JRC), UV-328 is included as being used in food contact materials (JRC, 2017). UV-328 is also part of the 2013 inventory list of the European Printing Ink Association (EuPIA) for additives in printing ink used on the non-food contact surface of food contact articles (EuPIA, 2013). In Switzerland, UV-328 is included in the "List of permitted substances for the production of packaging inks, and related requirements" of the Ordinance on Materials and Articles in Contact with Food (Swiss FDHA, 2020). In the USA, UV-328 is listed in the US Food and Drug Administration's (FDA) Inventory of Indirect Additives used in Food Contact Substances (US FDA, 2021). In Japan, UV-328 is in the 2020 Positive List for food contact plastics additives (MHLW, 2020). In China, UV-328 is included in the list of additives for plastic food contact materials and articles (NHFPC, 2016).

UV-328 has been reported to have three main uses in the automobile sector: (i) in optical polarizing plate and polarizing film for liquid crystal panels (of the super twisted nematic type) and meters mounted on vehicles; (ii) in paint; and (iii) in resin used for interior and exterior parts (e.g., door handles and levers) (JAPIA, 2021). The European Automobile Manufacturers' Association (ACEA) estimated the possible amount of replacement parts containing UV-328 as well as the amount of UV-328 contained in these replacement parts (Annex F, ACEA, 2022). ACEA highlights that the information is related to significant uncertainties. According to their estimation, the most relevant quantities of UV-328 in replacement parts are to be expected in components such as bumper systems, radiator grills, spoilers, car garnish, roof modules, soft/hard tops, trunk lids and rear window wipers (in decreasing order of relevance), but also in polarizing films of interior displays. Of note, these parts are mostly rather large plastic components, some of which are also painted. These are usually exterior vehicle parts that are exposed to light and therefore typically contain a light stabilizer. Based on the estimation provided by ACEA, it can be derived that more than 99% of UV-328 sold in replacement parts may be contained in bumper systems and radiator grills. Based on the feedback provided by ACEA and automotive associations in North America and Japan, UV-328 will be phased out in the mass production latest by 2025. Furthermore, replacement part applications will automatically phase out over time due to the continuous replacement of older vehicles with newer ones. Apart from automobiles (including motorcycles), replacement parts containing UV-328 are used for industrial machines (agricultural machinery, construction machinery, medical equipment, electric and electronic instruments) (Annex F, Japan, 2022). In coatings, the typically recommended concentration of UV-328 is between 1 and 3% (by weight, based on solids) (Hangzhou Sunny Chemical Corp Ltd., 2003). For the consumer use in automotive clear coat finish and topcoat glaze for boats, concentrations of UV-328 ranging up to 10% were identified in material safety data sheets in the USA (as reported in ECCC and Health Canada, 2016). In resin and paint used in the automotive sector UV-328 concentrations range between 0.1 and 1% (JAPIA, 2021).

In plastics, the recommended loading of UV-328 as an additive during manufacturing is typically 0.1–1% by weight (Hunan Chemical BV, 2016). Polymer-specific recommendations are 0.15–0.3% for PC, 0.2–0.4% for polyethylene (PE), 0.2–0.5% for PS and PVC and 0.3–0.5% for polyesters (Disheng Technology, 2017).

2.2.4 Findings from Studies on Plastic and Packaging Materials

Several studies have found UV-328 in plastics and packaging materials (Chang et al., 2013; Rani et al., 2017; Zhang et al., 2016). Zhang et al. (2016) found UV-328 in the range of 25–76 µg/g (0.0025–0.0076% by weight) in milk packaging and snack packaging together with other UV absorbers. Chang et al. (2013) reported a concentration of 2.01 µg/g of UV-328 in commercial polyethylene terephthalate (PET) beverage packaging and 13.88 µg/g in low-density polyethylene packaging. Rani et al. (2017) reported concentrations in the range of 0.0027–0.4 µg/g in newly-produced plastics. In addition, UV-328 has been detected in recycled post-consumer PET intended for subsequent manufacturing of food contact materials, although the concentration of UV-328 was not reported (Dutra et al., 2014).

Brosché et al. (2021) analyzed 24 samples of plastic pellets sold as high-density polyethylene and collected from 23 mostly developing countries around the world from local recycling industries for the presence of UV-328. UV-328 was detected in 17 of the 24 countries (71 % of samples, including countries where UV-328 production has not been reported in concentrations ranging between 0.102 and 334 µg/kg. Other UV-stabilizers such as UV-234, UV-326, UV-327 and UV-329 were also detected. The limit of detection was 0.03 µg/kg (Brosché et al., 2021).

Avagyan et al. (2015) measured UV-328 in various clothing articles. From 26 clothing articles made from different materials, UV-328 was detected at concentrations of 8.05 and 108 ng/g in two samples composed primarily from cotton. The use of UV-328 in textiles can also be a source of releases of UV-328 to the environment and wastewater treatment plants when textiles are washed. It was shown that after 10 wash cycles, as much as 80% of UV-328 was removed from textiles made from polyesters (Luongo et al., 2015).

In summary, UV-328 is used as a UV absorber and based on the available information, the main uses are in plastics such as PP, PS, PVC, polyurethane and rubbers used in the automotive industry, such as, automotive paints, coatings, sealants, adhesives, plastics and rubbers to protect materials from UV light-induced degradation or color-change, as well as various automotive fluids, such as, cooling and hydraulic liquids, and lubricants in motor oil. It can also be used as additives and printing inks in plastics and rubbers for outdoor furniture, construction materials and food packaging and in wood products. Other uses also include applications in leather and textiles as well as cosmetics. Use concentrations range from 0.1 to 10% by weight.

The information on specific exemptions for the use of UV-328 in accordance with the Stockholm Convention were listed in 2.1.

2.3. Chemical Alternatives

Chemical alternatives to UV-328 were identified in general terms (see Chapter 4.4). However, specific data for which specific alternative(s) is (are) being utilized as substitutes for UV-328 for each Specific Exemption could not be obtained to date as shown in the table below. Note: In the table below, each Specific Exemption is abbreviated, see table on page 11 above for the complete wording.

Specific Exemption	Typical Use Rate of UV-328	Existence of Alternative(s)	Chemical Identity of Alternative(s)	Trade Name(s) and/or Producers of Alternatives
Parts of Motor Vehicles	Unknown	Unknown	Unknown	Unknown
Industrial Coating Applications	Unknown	Unknown	Unknown	Unknown
Mechanical Separators in blood collection tubes	Unknown	Unknown	Unknown	Unknown
Triacetyl cellulose (TAC) film in polarizers	Unknown	Unknown	Unknown	Unknown
Photographic paper	Unknown	Unknown	Unknown	Unknown

2.4. Summary of best available technique (BAT) and best environmental practices (BEP) by Specific Exemption

The table below summarizes information on BAT and BEP for the UV-328 uses listed as Specific Exemptions. Please note, specific information cannot be obtained to date as shown in the table below. Note: Each Specific Exemption is abbreviated, please see pages 11 and 12 above for the complete wording.

Specific Exemption	BAT	BEP
Production of UV-328	Unknown	Unknown

Parts of Motor Vehicles	Unknown	Unknown
Industrial Coating Applications	Unknown	Unknown
Mechanical Separators in blood collection tubes	Unknown	Unknown
Triacetyl cellulose (TAC) film in polarizers	Unknown	Unknown
Photographic paper	Unknown	Unknown
Replacement Parts	Unknown	Unknown

2.5. Relationship to the Basel Convention

In addition to the provisions of the Stockholm Convention, those of the Basel Convention are directly relevant to the application of BAT and BEP to address UV-328 releases from waste. Considering that several waste streams, including plastic waste, are major potential UV-328-containing material flows, synergies between the Stockholm Convention and Basel Convention are of high importance.

The Basel Convention places obligations on countries that are Parties to, inter alia: minimize generation of hazardous waste; ensure that adequate disposal facilities are available; and ensure environmentally sound management of wastes.

General technical guidelines on the environmentally sound management of POPs wastes have been developed under the Basel Convention and can be used as a first reference. The specific technical guideline for UV-238 being developed under the Basel Convention contains in its section I.B.4 information on wastes and waste streams containing UV-328 and in its section IV.G.2. information on destruction and irreversible transformation methods. Wastes containing UV-328 at concentrations at or above a low POP content level must be disposed of in an effective and efficient way such that their POPs content is destroyed or irreversibly transformed, or otherwise disposed of in an environmentally sound manner.

Measures also address proper waste handling, collection, transportation and storage and ensure that emissions and related exposures to UV-328 from waste are minimized.

Establishment of the low POP content limit (LPCL) value and the guidelines, which are under development in cooperation with the Basel Convention, provide guidance for Parties to dispose of waste containing UV-328 in an environmentally sound manner.

3. Best Available Techniques (BAT) and Best Environmental Practices (BEP)

3.1. BAT and BEP for the use of UV-328 on parts of motor vehicles, such as bumper systems, radiator grills, spoilers, car garnish, roof modules, soft/hard tops, trunk lids and rear window wipers

UV-328 is used as a UV absorber as it can absorb the whole spectrum of UV light without being destroyed. Based on the available information, the main uses are in the automotive industry, such as, automotive paints, coatings, sealants, adhesives, plastics and rubbers to protect materials from UV light-induced degradation or color-change, as well as various automotive fluids, such as, cooling and hydraulic liquids, and lubricants in motor oil. In coatings, the typically recommended concentration of UV-328 is between 1.0 and 3.0% (by weight, based on solids) (Hangzhou Sunny Chemical Corp Ltd., 2003). For the consumer use in automotive clear coat finish and topcoat glaze for boats, concentrations of UV-328 ranging up to 10% were identified in material safety data sheets in the USA (as reported in ECCC and Health Canada, 2016). In resin and paint used in the automotive sector UV-328 concentrations range between 0.1 and 1% (JAPIA, 2021). For plastics, UV-328 is typically incorporated in concentrations ranging from 0.1 to 1% by weight during the manufacturing process. This careful calibration in the automotive paint and coatings sector is crucial to maintain the balance between UV protection and the mechanical integrity of the coatings.

No detailed information on relevant BAT and BEP principles could be obtained.

3.2. BAT and BEP for the use of UV-328 on industrial coating applications for motor vehicles, engineering machines, rail transportation vehicles, and heavy-duty coatings for large steel structures

Industrial coatings serve a wide range of purposes, with their primary role being to protect equipment from various forms of corrosion, which can be applied to a variety of surfaces, including concrete, timber, metal, plastic, glass, rubber, leather, and mortar.[1] UV-328 could enhance the durability and lifespan of industrial coatings by absorbing harmful UV radiation, which can otherwise lead to degradation of the coating material over time. UV-328 is often used with hindered amine light stabilizers to improve the resistance of paint loss of light, pulverization, bubbles. The typically recommended concentration of UV-328 in coatings is between 1.0 and 3.0% (by weight, based on solids) (Hangzhou Sunny Chemical Corp Ltd., 2003). The detailed industrial chemical process of incorporating UV-328 into industrial coatings is described as follows:

UV-328 is prepared in a form that can be easily incorporated into coating formulations. This might involve creating a masterbatch or pre-dispersion of UV-328 in a suitable solvent or carrier that is compatible with the coating system. The UV-328 preparation is then mixed with other components of the coating formulation, which may include polymers, pigments, fillers, catalysts, and other additives. The precise formulation depends on the desired properties of the final product, such as color, durability, and resistance to environmental factors. UV-328 is chosen for its excellent UV absorption capabilities, which helps in protecting the coating and the underlying material from UV-induced degradation. The mixing process must ensure uniform distribution of UV-328 throughout the coating material to ensure effective UV protection. The coating formulation containing UV-328 is applied to the substrate that needs protection. This can be achieved through various techniques such as spraying, brushing, dipping, or rolling, depending on the nature of the substrate and the specific requirements of the coating. After application, the coating needs to be cured, which may involve air drying, heating, or exposure to UV light, depending on the type of coating. Curing ensures that the coating adheres well to the substrate and forms a durable, protective layer.

No detailed information on relevant BAT and BEP principles could be obtained.

3.3. BAT and BEP for the use of UV-328 on mechanical separators in blood collection tubes

UV-328 is incorporated as a UV stabilizer in the manufacture of mechanical separator components used in blood collection tubes by being a part of the thermoplastic elastomer (TPE) material. This material is utilized to produce the mechanical separator, with UV-328 acting to prevent the degradation of the plastic separator due to UV light exposure. “Specifically, UV-328 is imported as a component of the TPE, comprising less than 1% by weight of the formulation” (Becton, Dickinson U.K. Limited, 2022).

No detailed information on relevant BAT and BEP principles could be obtained.

3.4. BAT and BEP for the use of UV-328 on triacetyl cellulose (TAC) film in polarizers

The application of UV-328 to the TAC film in polarizers is aimed at effectively ensuring protection against ultraviolet (UV) radiation while maintaining optimal performance and longevity of the LCD.

[1] Industrial Coatings: Types, Applications, Benefits, and Techniques.

No detailed information on relevant BAT and BEP principles could be obtained.

3.5. BAT and BEP for the use of UV-328 on photographic paper

No detailed information on relevant BAT and BEP principles could be obtained.

3.6. BAT and BEP for the use of UV-328 for replacement parts for articles used on stationary industrial machines in agriculture, forestry and construction

The incorporation of UV-328 into stationary industrial machines typically involves its application to components susceptible to UV light degradation, such as plastic parts, rubber seals, and protective coatings. The goal is to extend the lifespan of these components by protecting them from the harmful effects of UV radiation, thus ensuring the durability and reliability of the machinery.

Initially, a specialized chemical formulation is prepared, incorporating UV-328 at a precise concentration optimal for UV protection without compromising the physical properties of the target materials—plastics, coatings, or rubbers used in machinery. Utilizing advanced application techniques—such as electrostatic spraying for coatings or extrusion mixing for plastics and rubbers—the formulated mixture with UV-328 is evenly applied or integrated into the machine components. This stage is critical for achieving homogeneous distribution of the UV stabilizer across all treated surfaces. Post-application, the treated components undergo a curing process tailored to the material composition and the specific formulation of the UV-328 mixture. Methods may include thermal curing, UV light exposure, or ambient air drying, each chosen based on efficiency and environmental impact considerations (Patil *et al.*, 2023).

No detailed information on relevant BAT and BEP principles could be obtained.

3.7. BAT and BEP for the use of UV-328 for production of replacement parts for liquid crystal displays

No detailed information on relevant BAT and BEP principles could be obtained.

4. General principles and guidance on BAT and BEP for managing UV-328

4.1 General Considerations

General considerations on BAT and BEP for managing UV-328 include the following:

- Stay informed of regulatory changes and update operational practices to maintain compliance with all applicable laws and standards.
- Maintain thorough documentation of all permits, processes, waste management practices, and compliance efforts with local, state and national regulations.
- At all times, ensure all processes and chemicals utilized comply with the regulatory requirements across all jurisdictions where the products are manufactured and sold.
- Maintain transparent communication with regulatory bodies, employees, and the local community about environmental management practices and performance.
- Keep an up-to-date safety data sheet (SDS) of all chemicals used on site on file and make it available to all employees.
- Provide appropriate personal protective equipment (PPE) to workers, this may include respirators, gloves, and protective clothing.

- Conduct regular training sessions on compliance, best practices, safe handling of chemicals and emergency response for all employees.
- Develop and implement comprehensive occupational health and safety protocols for handling UV-328, including training on the use of PPE and emergency response procedures.
- Establish a reporting mechanism for employees to suggest improvements or report potential environmental issues.
- Monitor air quality in the workplace to ensure compliance, protecting workers' health.
- Foster a culture of environmental responsibility among employees by incentivizing the identification and implementation of any improvement ideas.
- Implement continuous monitoring systems to track emissions, waste generation, and energy use.
- Invest in research and development to find safer and more sustainable alternatives to UV-328.
- Prioritize the use of more sustainable chemicals and processes that minimize or eliminate the use and generation of POPs and/or hazardous substances in the design, manufacture, and application.
- Partner with suppliers who adhere to sustainable practices in the production and supply of raw materials, including UV-328. Certification through recognized environmental standards (e.g., ISO 14001 for environmental management) should be a prerequisite for supplier selection.
- Conduct audits to ensure suppliers' adherence to environmental and safety standards.

Material sourcing, storage and handling considerations include the following:

- Utilize inventory management software to track raw material use and ensure optimal stock levels, reducing the potential for over-ordering and waste.
- Utilize smart monitoring systems in storage areas and store all chemicals in containers that are clearly labeled and resistant to degradation. Use climate-controlled storage areas to prevent exposure to extreme temperatures or sunlight.
- Implement spill containment measures in storage areas, such as secondary containment systems and spill pallets.
- Use automated, vacuum-sealed material transfer systems to move chemicals, including UV-328, from storage to the production area, minimizing exposure to the environment and reducing the risk of spillage.
- Design material handling systems to minimize for example, dust formation and volatile organic compound (VOC) emissions. This includes sealed conveying systems and the use of dust suppression technologies during the weighing and mixing of raw materials.
- Implement closed-loop processes in mixing and application stages to reduce exposure and environmental release.
- Where feasible, employ micro-encapsulation techniques to bind UV-328 in a polymer matrix (master batch), reducing volatility and potential for worker exposure during handling.

Production process considerations include the following:

- Use process optimization software to continually assess the efficiency of additive use, ensuring that the smallest effective quantity is utilized.
- Regularly review and optimize manufacturing processes to enhance efficiency, reduce chemical use, and minimize waste and emissions.

- Utilize formulation software to calculate the optimal amount of stabilizer needed to achieve desired results, reducing overuse and minimizing waste.
- Periodically review and adjust formulations based on performance data and environmental impact assessments.
- Use advanced, automated dosing systems that ensure precise measurements and uniform dispersion of additives for all applications, such as automotive coatings or parts, TPE mixtures, minimizing excess use and waste. Reprogram robots in, for example, automotive seat and interior manufacturing plants to optimize spray width and improve accuracy.
- Implement precision electrostatic spray or curtain coating techniques that minimize overspray and ensure uniform application of the UV-328-containing coating on the TAC films.
- Implement enclosed manufacturing processes that contain any vapors or particulates within the system, greatly reducing occupational exposure and environmental release.
- Utilize UV curing technology, which can be more energy-efficient and emit fewer VOCs compared to traditional thermal curing methods.
- Design curing chambers with enhanced airflow management and afterburners to capture and decompose any residual VOCs from the curing process.
- Regular maintenance and calibration of equipment to prevent leaks and inefficiencies.
- Implement energy management systems (e.g., ISO 50001) to monitor and reduce energy use in production processes.
- Explore the adoption of renewable energy sources (solar, wind) to power manufacturing facilities.
- Where possible and feasible, utilize energy recovery systems to capture and reuse heat generated, reducing overall energy consumption.
- Equip production lines with machinery that has been certified for energy efficiency (e.g., ENERGY STAR-rated equipment). Additionally, consider the integration of regenerative heating systems that captures and reuses heat generated during the manufacturing process.
- Implement closed-loop cooling systems for machinery, which reduce water consumption by recycling and reusing water within the production facility.
- Explore and utilize Low-Energy Curing Technologies. Explore the use of electron beam curing or UV curing, where applicable, as alternatives to traditional thermal curing methods, offering potential reductions in energy use and processing time.

Regarding quality control systems, considerations include the use of advanced quality control systems to monitor product quality throughout the production process and reduce the need for rework and the associated additional resource consumption.

Emission control/abatement considerations include the following:

- Develop a spillage control plan, including spill kits at handling stations, and train personnel in spill response techniques to minimize environmental contamination and to ensure proper waste management.
- Adopt comprehensive waste management strategies that involve the reduction, re-use, and recycling of materials that do not contain UV-328, and ensure the environmentally sound disposal of UV-328 according to the Basel Convention General and specific technical guidelines on UV-328 waste (see Chapter 2.3). Where appropriate, procedures and processes for managing hazardous wastes should be considered for handling, collecting, packaging, labelling, transporting and storing

UV-328 wastes in order to prevent spills and leaks resulting in worker exposure, releases to the environment or exposure of the community.

- Install high-efficiency particulate air filters and activated carbon systems to capture airborne particles and volatile organic compounds (VOCs) from production processes.
- Regularly inspect and maintain emission control systems to ensure optimal performance.
- Use solvent recovery units to capture and recycle solvents from the coating application or any other suitable process.
- Implement closed-loop systems for the recovery and reuse of process water, minimizing wastewater generation.
- Where feasible, employ zero liquid discharge systems that treat and recycle wastewater, eliminating liquid waste discharge and reducing water consumption by reclaiming purified water for use in the manufacturing process. Otherwise, treat any wastewater to reduce contaminants before discharge into the environment.
- Implement thermal oxidizers to treat exhaust streams containing VOCs, POPs and other chemicals from the coating process, converting them into water vapor and carbon dioxide through combustion at high temperatures.
- For processes emitting chemicals that can be broken down by UV light, consider UV photolysis systems that decompose hazardous compounds in the exhaust before release.
- Develop a system for recycling scrap and off-spec materials not containing or contaminated with UV-328 where feasible, reducing the volume of waste generated and promoting resource efficiency.
- Integrate renewable energy sources, such as solar or wind power, into the energy supply for the manufacturing facility to reduce the carbon footprint of the production process.

Ongoing monitoring and management considerations include the following:

- Conduct regular Environmental Impact Assessments (EIAs) to evaluate the impact of the manufacturing process on the environment, particularly focusing on the use of UV-328, and adjust processes based on findings to minimize environmental impact.
- Utilize continuous emission monitoring systems (CEMS) and regular environmental auditing to track and manage emissions and ensure compliance with environmental standards.
- Conduct lifecycle assessments (LCA) to understand and minimize the environmental impact across the entire lifecycle of automotive parts, from raw material extraction to end-of-life disposal.

4.2 Environmental Management Systems

A number of environmental management techniques are determined as BEP. An Environmental Management System (EMS) is a tool that operators can use to address these design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way. An EMS includes the organizational structure, responsibilities, practices, procedures, processes and resources for developing, implementing, maintaining, reviewing and monitoring the environmental policy. Environmental Management Systems are most effective and efficient where they form an inherent part of the overall management and operation of an installation. The scope and nature of an EMS will generally be related to the nature, scale and complexity of the facility, and the range of environmental impacts it may have (GTZ, 2008, ZDHC, 2015).

BEP is to implement and adhere to an EMS that incorporates the following features:

- Commitment, leadership and accountability of the management, including senior management, for the implementation of an effective EMS;
- An analysis that includes the determination of the organisation's context, the identification of the needs and expectations of interested Parties, the identification of characteristics of the installation that are associated with possible risks for the environment (or human health) as well as of the applicable legal requirements relating to the environment;
- Definition and/or development of an environmental policy for implementation that includes the continuous improvement of the environmental performance of the installation led by top management (senior corporate leadership commitment and accountability is regarded as a precondition for a successful application of the EMS);
- Establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;
- Planning and establishing of the necessary procedures (including corrective and preventive actions where needed), to achieve the environmental objectives and avoid environmental risks;
- Implementation of the procedures, paying particular attention to:
    - Organizational structure and responsibility;
    - Provision of the financial and human resources needed;
    - Training, awareness and competence;
    - Communication (internal and external);
    - Employee involvement;
    - Documentation;
    - Efficient operational planning and process control;
    - Maintenance programme;
    - Emergency preparedness and response;
    - When (re)designing a (new) installation or a part thereof, consideration of its environmental impacts throughout its life, which includes construction, maintenance, operation and decommissioning;
    - Implementation of a monitoring and measurement programme;
    - Safeguarding compliance with environmental legislation;
- Performance checks and taking corrective action:
    - Monitoring and measurement;
    - Records Maintenance;
    - Establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;
    - Performing independent (where feasible) internal auditing to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;
    - Evaluation of causes for nonconformities, implementation of corrective actions in response to nonconformities, review of the effectiveness of corrective actions and determination of whether similar nonconformities exist or could potentially occur.

Four additional features are considered as progressive measures; their absence, however, is generally not inconsistent with BEP:

- Examination and validation of the management system and audit procedure by an accredited certification body or an external EMS verifier;
- Preparation and publication of a regular environmental statement describing all the significant environmental aspects of the facility, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate (i.e., continuous improvement plan and annual progress report);
- Consideration of applicable industry-specific standards, when available;
- Implementation and adherence to an internationally accepted EMS, such as ISO 14001 or the Eco Management and Audit Scheme.

This last voluntary step could give higher credibility to the EMS, particularly internationally accepted and transparent standards, such as ISO9001 and ISO14001, including Responsible Care®. Non-standardized systems can in principle be equally effective provided that they are properly designed and implemented.

4.3. Life cycle management

Life cycle management (LCM) is an integrated concept for managing the total life cycle of goods and services towards more sustainable production and consumption, building on the existing procedural and analytical environmental assessment tools and integrating economic, social and environmental aspects. LCA is a comprehensive technique that quantifies ecological and human health impacts of an article or system over its complete life cycle (UNEP, 2011; European Commission JRC-IES 2010). Releases of UV-328 occur during all life cycle stages due to past and present production, manufacturing, transportation and final use of the substance as well as during the use, disposal and end-of-life treatment of products containing UV-328 (UNEP, 2023). A targeted version of the LCA/LCM approach, which defines the boundaries, could be useful to formulate UV-328 management strategies in developing countries and countries with economies in transition, with recycling technologies and approaches that are more labour intensive. This approach could lead to better separation and sorting of recycled materials that do not contain UV-328, and thus achieve effectively handling of wastes containing UV-328 in an environmentally sound manner.

In accordance with Article 6 of the Stockholm Convention, stockpiles consisting of or containing UV-328 should be managed in a safe, efficient and environmentally sound manner. After the stockpiles are no longer allowed to be used and all exemptions have expired, they should be considered as waste. The wastes, including products and articles upon becoming wastes, consisting of, containing or contaminated with UV-328, should be handled, collected, transported and stored in an environmentally sound manner. They are not permitted to be subjected to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of UV-328. Comprehensive waste management strategies should be in accordance with the Basel Convention General and specific technical guidelines[2] on UV-328 waste to ensure its environmentally sound disposal. The destruction or irreversible transformation of the UV-328 content of waste and avoiding its recovery, recycling, reclamation, direct reuse or alternative uses is seen as the most efficient way to ensure the protection of human health and the environment and ensure no further spread or emission of the substance.

4.4. Producer responsibility

The Stockholm Convention's BAT and BEP guidelines (UNEP 2007/2019) describe principles such as sustainable development, sustainable consumption, the precautionary approach, integrated pollution, internalization of environmental costs, extended producer responsibility, cleaner production, life cycle

[2] Basel Convention General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants and technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with UV-328.

assessment, and life cycle management. These principles are all relevant to secure BAT/BEP for the management of UV-328-containing material flows, in particular that of producer responsibility.

Producers' and other stakeholders' responsibilities have been established through initiatives such as the EU's integrated product policy;[3] its thematic strategy on the prevention and recycling of waste[4] and associated framework directives;[5] the extended producer responsibility programme of the Organisation for Economic Co-operation and Development and related guidance (OECD 2001); the concept of product stewardship; and through other initiatives. In some cases, it may be useful to oblige producers to take back certain end-of-life products and to ensure their environmentally sound management. The guidance on sampling, screening, and analyzing POPs in products and recycling provides guidance for monitoring industrial and unintentional POPs in products currently in use and within recycling streams for those listed under the Stockholm Convention (UNEP, 2021). The guidance is regularly reviewed to ensure that information for managing POPs, like UV-328, stay current and aligned with the latest environmental and scientific research.

UV-328-containing articles include important material flows for which producer responsibility could be the key for their global management. The European Automotive Industry represented by ACEA is currently in the process of phasing out UV-328. By 2026 the substance will be phased out from their new products. In order to address each individual waste stream arising from an exempted use of UV-328 in replacement parts, extended producer responsibility policies could be implemented. Such policies extend the responsibility of the producer also to the waste stage of their sold products and can help countries manage the wastes arising from the use of UV-328 and other POPs.

4.5. Alternatives

Based on the POPRC general guidance on considerations related to alternatives and substitutes for listed POPs and candidate chemicals, alternatives should be available, accessible, efficient as well as technically feasible. Moreover, the adoption of alternative substances or processes should ideally not substantially increase costs. This includes manufacturing costs as well as environmental and health costs related to the adoption of alternative substances or processes. Safer alternatives should be pursued, i.e., alternatives that either reduce the potential for harm to human health or the environment or that have not been shown to meet the Annex D screening criteria for listing a chemical under the Convention as a persistent organic pollutant. (UNEP/POPS/POPRC.5/10/Add.1 and UNEP/POPS/POPRC.18/11/Add.2).

Only general information on the availability of alternatives to UV-328 could be obtained. Information on which exact alternative is suitable to replace UV-328 in any of the specific exemption could not be obtained to date.

[3] Green Business - European Commission (europa.eu).
[4] Waste and recycling - European Commission (europa.eu).
[5] Waste Framework Directive - European Commission (europa.eu).

Phenolic benzotriazoles are technically the most important UV absorbers (ECHA, 2020). In the automotive industry, they have been extensively used as light stabilizers in plastic and coating applications (Annex F, ACEA, 2022). UV-328 can be substituted with other benzotriazoles (1-to-1 substitution) given that the necessary research efforts for the application-specific substitution of UV-328 are carried out (Annex F, ACEA, 2022). Other phenolic benzotriazoles used for the same applications as UV-328 (ECHA, 2020; Germany, 2014) are included in Table 3. Some of these benzotriazoles are under PBT assessment in the EU while others may still pose potential harm to human health and/or the environment.

Table 3. Overview of phenolic benzotriazoles not currently listed as Substances of Very High Concern (SVHC) in the EU. Source: Annex F, UK, 2022; BAuA, 2022; ECHA, 2022a; Germany, 2014.

Benzotriazoles	Availability	Remark
UV-P **(2-(2*H*-benzotriazol-2-yl-*p*-cresol);** **CAS No. 2240-22-4**	This substance is registered under the REACH Regulation and is manufactured in and/or imported to the European Economic Area (EEA), at ≥ 1,000 to < 10,000 t/a (ECHA, 2022a).	Under PBT assessment (ECHA, 2022a).[6]
UV-234 **(2-(2*H*-Benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol);** **CAS No. 70321-86-7**	This substance is registered under the REACH Regulation and is manufactured in and/or imported to the EEA, at ≥ 1,000 to < 10,000 t/a (ECHA, 2022a).	Under PBT assessment (ECHA, 2022a). BAuA (2022) has indicated a tentative plan to submit a proposal in 2023 to identify the substance as SVHC due to its vPvB properties.
UV-360 **(2-2'-Methylenebis[6-(2*H*-benzotriazol-yl)-4-(1,1,3,3-tetrametyhlbutyl)phenol]);** **CAS No. 103597-45-1**	This substance is registered under the REACH Regulation and is manufactured in and/or imported to the EEA, at ≥ 100 t/a (ECHA, 2022a).	According to the harmonized classification and labelling approved by the EU, this substance may cause long lasting harmful effects to aquatic life (H413) (ECHA, 2022a).
UV-571 **(2-(2*H*-benzotriazol-2-yl)-6-dodecyl-4-methylphenol);** **CAS No. 125304-04-3**	This substance is not registered under the EU REACH regulation; however, internet searches have identified international suppliers. It is unclear if the substance is widely available (Annex F, UK, 2022).	According to the classification provided by companies to ECHA in CLP notifications this substance is toxic to aquatic life with long lasting effects (ECHA, 2022a).
UV-928 **(2-(2*H*-Benzotriazol-2-yl)-6-(1-methyl-1-phenylethyl)-4-(1,1,3,3-tetramethylbutyl)phenol);** **CAS No. 73936-91-1**	This substance is registered under the REACH Regulation and is manufactured in and/or imported to the EEA, at ≥ 1,000 to < 10,000 t/a (ECHA, 2022a).	Under PBT assessment (ECHA, 2022a). According to BAuA (2022), the available evidence might also be sufficient to conclude that UV-928 fulfills the REACH criteria for vPvB substances. The necessity of a proposed bioaccumulation test is still pending.[7]

Most of the alternatives outlined in Table 3 are under assessment in the EU regarding their PBT/vPvB properties, and the rest may also have some harmful effects. Therefore, their use is possibly related to specific risks for health and/or the environment. Hence, replacing UV-328 with these alternatives may be a regrettable substitution.

Benzophenones represent another class of UV absorbers, which can be used as potential substitutes for UV 328 (ECHA, 2020). However, certain benzophenones are suspected to be endocrine disruptors (Carstensen et al., 2022; Germany Annex XV Dossier, 2014; Watanabe et al., 2015; Zheng et al., 2020) and hence, there is a risk for regrettable substitution (Baoxu Chemical; Basu et al., 2009). Other phenolic benzotriazoles may be more suitable alternatives (Annex F, UK, 2022).

[6] According to BAuA (2022), UV-P can be considered very persistent (vP), borderline toxic (T) but not bioaccumulative (B) based on a bioconcentration factor (BCF) obtained from a fish test. Concerns for terrestrial bioaccumulation and mobility remain for UV-P and that further investigation is needed BAuA (2022).

[7] Further information on the testing proposal is available at: Previous Testing Proposals - ECHA (europa.eu).

Further substances which can be used for the substitution of UV-328 and the protection of plastics from UV radiation include hindered amine light stabilizers (HALS) (ECHA, 2020). Some HALS are related to specific adverse effects and hence, there is a risk for regrettable substitution. Safer alternatives should therefore be selected carefully.

Other alternatives may be oxalanilides (Schaller et al., 2008). One example for an UV absorber of the oxalanilide class is UV-312 (Annex F, UK, 2022). UV-312 is registered under the REACH Regulation and is manufactured in and/or imported to the EEA at quantities higher than 10 t/a suggesting that the substance is widely available. Regarding potential risks, no hazards have been identified for UV-312 (ECHA, 2022a). Oxalanilides represent an early class of UV absorbers and have been replaced in several applications by various benzotriazoles (Annex F, IPEN and ACAT, 2022; Schaller et al., 2008).

Cyanoacrylates represent another potential alternative UV absorber (Annex F, UK, 2022; Germany, 2015). One example is UV-3035 which can be used as light stabilizer in various polymers including, among others, PVC and PS. Most commonly, it is used in the electronics and building industry (MPI Chemie BV, 2022). However, the substance is known to be irritating to the eyes and skin, cause damage to the organ and it is toxic to aquatic life (ECHA, 2022d).

Depending on substrate and durability requirements of the final plastic application, alternative chemistries indicated here are available to stabilize plastics, also within the benzotriazole class. Each UV absorber has its specific substance properties like its individual UV absorbance spectrum and its inherent physicochemical properties. HALS cannot simply replace a UV absorber and also benzophenones and oxalanilides do not have the same performance properties as UV-328. Therefore, the selection of a replacement candidate must be carefully evaluated in order to avoid reduction of the specified product performance. For the identification of safer and appropriate alternatives for individual applications, information available e.g., in Grob et al. (2016) can be consulted. Information on the status of alternatives' regulatory assessments is available on relevant websites of authorities or other institutions.

4.6. Identification and monitoring of UV-328 in products and articles and on the environment

Identification and monitoring of UV-328 in products and article

UV-328 can be identified in various consumer products and articles, particularly those that require light stabilization against UV radiation. It is commonly used as a UV absorber in plastics, coatings, and other materials to prevent degradation caused by exposure to sunlight. To monitor UV-328 in these products, analytical techniques such as gas chromatography-mass spectrometry (GC-MS), or liquid chromatography-mass spectrometry (LC-MS) can be employed. These methods allow for the detection and quantification of UV-328 in different matrices (UNEP, 2021).

Identification and monitoring of UV-328 on the environment

The environmental levels of UV-328 have been reported in most environmental compartments, including soil, water bodies (Amankwah *et al.*, 2024; Montesdeoca-Esponda *et al.*, 2021; Yamashita *et al.*, 2021), sediment (Brorström-Lundén *et al.*, 2011; Cantwell *et al.*, 2015; Liu *et al.*, 2024; Montesdeoca-Esponda *et al.*, 2021; Wick *et al.*, 2016), air, wastewater treatment plant influent, effluent and biosolids (Amankwah *et al.*, 2024; Brorström-Lundén *et al.*, 2011; Langford *et al.*, 2015; Montesdeoca-Esponda *et al.*, 2020; Montesdeoca-Esponda *et al.*, 2021; Nakata & Shinohara, 2010), breastmilk (Kim *et al.*, 2019) and wildlife (Amankwah *et al.*, 2024; Khare *et al.*, 2023; Langford *et al.*, 2015; Montesdeoca-Esponda *et al.*, 2021; Nakajima *et al.*, 2023; Struk-Sokołowska *et al.*, 2024; Wang *et al.*, 2022; Wick *et al.*, 2016). Given its potential for long-range environmental migration, it is important to track its distribution and concentration in the environment and set up long term environmental monitoring of appropriate matrices. The detection methods for environmental samples are similar to those used in product analysis, eg GC-MS and LC-MS. Isolation of UV-328 from environmental samples is similar to other organic contaminants such as current use pesticides, phthalate plasticizers and brominated and organophosphate ester flame retardants. This involves such processes as accelerated solvent extraction (ASE) (Kim *et al.*, 2019; Lai *et al.*, 2013), solid-phase extraction (SPE) (Liu *et al.*, 2014; Mao *et al.*, 2024; Sarah *et al.*, 2019), ultrasonication (Wang et al., 2022) and a new technique of microwave assisted extraction (Montesdeoca-Esponda *et al.*, 2021). In the UK, UV-328 was added to the EA's GC-MS target screen for water samples following the EA's Prioritization and Early Warning System screening, in June 2021 (Annex F, UK, 2022).

References

Annex E, (2021). Annex E information (risk profile) on UV-328. Submission of information from Parties and observers as specified in Annex E to the Stockholm Convention pursuant to Article 8 of the Convention. http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC16/POPRC16Followup/UV328submission/tabid/8761/Default.aspx

Annex F, ACEA (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, EU (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, IPEN and ACAT (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Japan (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Monaco (2022). Submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Netherlands (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Norway (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Republic of Belarus (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, Republic of Korea (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Annex F, UK (2022). Form for submission of information specified in Annex F to the Stockholm Convention pursuant to Article 8 of the Convention.

Amankwah, B.K., Šauer, P., Grabicová, K., von der Ohe, P.C., Ayıkol, N.S., & Kroupová, H.K. (2024) 'Organic UV filters: Occurrence, risks and (anti-)progestogenic activities in samples from the Czech aquatic environment and their bioaccumulation in fish', *Journal of Hazardous Materials*, 471, 134338. https://doi.org/10.1016/j.jhazmat.2024.134338.

Avagyan, R., Luongo, G., Thorsén, G., & Östman, C. (2015). Benzothiazole, benzotriazole, and their derivates in clothing textiles—a potential source of environmental pollutants and human exposure. Environmental Science and Pollution Research, 22(8), 5842–5849. https://doi.org/10.1007/s11356-014-3691-0.

Baoxu Chemical Overall Introduction of UV Absorber. (2022). from https://www.additivesforpolymer.com/overall-introduction-uv-absorber/.

Basu, M., Sarkar, S., Pande, S., Jana, S., Kumar Sinha, A., Sarkar, S., Pradhan, M., Pal, A., & Pal, T. (2009). Hydroxylation of benzophenone with ammonium phosphomolybdate in the solid state via UV photoactivation. *Chemical Communications*, 46, 7191. https://doi.org/10.1039/b905718h.

BAuA (2022). Regulatory Management Option Analysis Conclusion Document. https://echa.europa.eu/assessment-regulatory-needs/-/dislist/details/0b0236e180785a06.

Becton, Dickinson U.K. Limited (2022). REACH – Applications for Authorisation AFA017-01 – UV-328. Available online at: https://consultations.hse.gov.uk/crd-reach/reach-afa017-01/ Accessed 26 November, 2024.

BenchChem (n.d.). *UV-328, Cat. No. B058241*. Molecular formula: $C_{22}H_{29}N_3O$, CAS No. 25973-55-1. Molecular weight: 351.5 g/mol. InChI Key: ZMWRRFHBXARRRT-UHFFFAOYSA-N. Available at: https://www.benchchem.com/synthesis/pse-b47535cb496g4e7dce20cde85d301b45.

Bolgar, M., Hubball, J., Groeger, J., & Meronek, S. (2016). Handbook for the chemical analysis of plastic and polymer additives (Vol. 4, Issue 1).

Brorström-Lundén, E., Hansson, K., Remberger, M., Kaj, L., Magnér, J., Andersson, H., Haglund, P., Andersson, R., Liljelind, P., & Grabic, R. (2011). Screening of benzothiazoles, benzenediamines, dicyclohexylamine and benzotriazoles 2009, Report B2023 *IVL-Swedish Environmental Research Institute*, 1–53.

Brosché, S., Strakova, J., Bell, L., & Karlsson, T. (2021). Widespread Chemical Contamination of Recycled Plastic Pellets Globally. https://ipen.org/sites/default/files/documents/ipen-recycled-plastic-pellets-v1_2.pdf.

Carstensen, L., Beil, S., Börnick, H., & Stolte, S. (2022). Structure-related endocrine-disrupting potential of environmental transformation products of benzophenone-type UV filters: A review. *Journal of Hazardous Materials*, 430, 128495. https://doi.org/10.1016/j.jhazmat.2022.128495.

Cantwell, M.G., Sullivan, J.C., Katz, D.R., Burgess, R.M., Hubeny, J.B., & King, J. (2015) 'Source determination of benzotriazoles in sediment cores from two urban estuaries on the Atlantic Coast of the United States', *Marine Pollution Bulletin*, 101(1), pp. 208–218. https://doi.org/10.1016/j.marpolbul.2015.10.075.

Chang, L., Bi, P., Liu, Y., Mu, Y., Nie, F., Luo, S., & Wei, Y. (2013). Simultaneous analysis of trace polymer additives in plastic beverage packaging by solvent sublation followed by high-performance liquid chromatography. Journal of Agricultural and Food Chemistry, 61(29), 7165–7171. https://doi.org/10.1021/jf401748a.

Denghel, K. H. (2021). Human metabolism and biomonitoring of UV 328 (2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol). Friedrich-Alexander-Universität Erlangen-Nürnberg. https://nbn-resolving.org/urn:nbn:de:bvb:29-opus4-181524.

Disheng Technology (2017). UV Absorber 328. https://www.knowde.com/stores/disheng-technology/products/disheng-technology-uv-absorber-uv-328

ECHA (2014). Member State Committee Support Document for Identification of 2-(2H-Benzotriazol-2-yl)-4,6-diterpentylphenol (UV-328) as a substance of very high concern because of its PBT/vPvB properties. https://echa.europa.eu/documents/10162/78b46a52-7b7c-c7ae-d5d7-2df3d2ef3a21.

ECHA (2020). Estimating the number and types of applications for 11 substances added to the Authorisation List in February 2020 (Issue February). https://doi.org/10.2823/11134.

ECHA (2022a). Information on Chemicals. Accessed March 20, 2022, from https://echa.europa.eu/information-on-chemicals.

ECHA (2022b). REACH Registration Dossier for 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol. Accessed March 8, 2022, from https://echa.europa.eu/registration-dossier/-/registered-dossier/5280/1/2.

ECHA (2022d). Substance Infocard on Etocrilene. Accessed May 11, 2022, from https://echa.europa.eu/substance-information/-/substanceinfo/100.023.663.

Environment and Climate Change Canada (ECCC) and Health Canada. 2016. Screening Assessment Report. Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylpropyl)- (BDTP). Chemical Abstracts Service Registry Number 25973-55-1. May 2016. https://publications.gc.ca/pub?id=9.820931&sl=0.

EuPIA (2013). Inventory list–Version December 2013 comprising packaging ink raw materials applied to the non-food contact surface of food packaging.

European Commission Joint Research Centre (JRC) (2017). Food flavourings, food additives and food contact materials exposure tool. European Commission, Joint Research Centre (JRC) [Dataset].

European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability (IES) 2010. International Reference Life Cycle Data System (ILCD) Handbook -General guide for Life Cycle Assessment -Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union.

Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. (1989). *Vogel's Textbook of Practical Organic Chemistry*. 5th ed. London: Longman, p.1163.

Gérardy, R. & Monbaliu, J.C.M. (2015). Preparation, Reactivity, and Synthetic Utility of Simple Benzotriazole Derivatives. In: Monbaliu, JC. (eds) *The Chemistry of Benzotriazole Derivatives*. Topics in Heterocyclic Chemistry, vol. 43, pp.1–66. Cham. Available at: https://doi.org/10.1007/7081_2015_179 (Accessed 26 Nov. 2024).Germany (2014). Annex XV Report: Proposal for Identification of a Substance of Very High Concern on the Basis of the Criteria set out in REACH 57: UV-328.

Germany (2015). Proposal for identification of a substance of very high concern on the basis of the criteria set out in REACH article 57. Substance Name: 2,4-Di-tert-butyl-6-(5-chlorobenzotriazol-2-yl)phenol (UV-327). https://echa.europa.eu/documents/10162/755b24e4-40dc-455b-afc0-b5e4e9045701.

Germany Annex XV Dossier (2014). Proposal for identification of a substance as a CMA 1A or 1B, PBT, vPvB or a substance of an equivalent level of concern. Identification of UV-328 as SVHC. https://echa.europa.eu/documents/10162/13641/rac_opinion_annex_UV-328_en.pdf/6d264702-380f-45d4-8022-fb59ca44740f.

Grob, M., Huber, G., Herbst, H., Gal, A. Le, Müller, D., Priest, H., & Tartarini, C. (2016). Lichtschutzmittel. In Handbuch Kunststoff Additive. Carl Hanser Verlag GmbH & Co. KG.

(GTZ) Deutsche Gesellschaft für Technische Zusammenarbeit. (2008). Chemical Management Guide for Small and Medium Sized Enterprises Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety. August 2008. http://www.mtpinnacle.com/pdfs/Guide_E_300708.pdf

Hangzhou Sunny Chemical Corp Ltd. (2003). UV absorber: UV-328. http://www.sunnychemical.com/UV-328.htm.

Haruhiko, Nakata, Ryu-ichi, & Shinohara (2010). *Concentrations of Benzotriazole UV Stabilizers and Polycyclic Musks in Wastewater Treatment Plant Samples in Japan*.

Hunan Chemical BV (2016). Technical Data Sheet, UV-328. https://hunan-chem.com/wp-content/uploads/2016/06/UV-Absorber-328.pdf.

JAPIA (2021). Japan Auto Parts Industries Association (JAPIA). Response to ECHA Public Consultation.

Jungclaus, G., Avila, V. and Hites, R. (1978) Organic compounds in an industrial Wastewater: a case study of their environmental impact. Environmental Science & Technology 12(1), 88-96.

Kale, R.R., Prasad, V., Mohapatra, P.P. & Tiwari, V.K. (2010). Recent developments in benzotriazole methodology for construction of pharmacologically important heterocyclic skeletons. *Monatshefte für Chemie - Chemical Monthly*, 141, pp.1159–1182. Available at: https://link.springer.com/article/10.1007/s00706-010-0371-7 (Accessed 26 Nov. 2024).

Khare, A., Jadhao, P., Kawre, S., Kanade, G., Patil, M., Vaidya, A. N., & Kumar, A. R. (2023). Occurrence, spatio-temporal variation and ecological risk assessment of benzotriazole ultraviolet stabilizers (BUVs) in water and sediment of rivers in central India. Science of The Total Environment, 882, 163381.

Khare, A., Pradip, J., Atul Narayan, V., & Asirvatham Ramesh, K. (2022). Benzotriazole UV Stabilizers (BUVSs) in the Environment : Much More than an Emerging Contaminant of Concern. https://doi.org/10.21203/rs.3.rs-1202371/v1.

Kim, J.-W., Chang, K.-H., Prudente, M., Viet, P.H., Takahashi, S., Tanabe, S., Kunisue, T., & Isobe, T. (2019) 'Occurrence of benzotriazole ultraviolet stabilizers (BUVSs) in human breast milk from three Asian countries', *Science of The Total Environment*, 655, pp. 1081–1088. https://doi.org/10.1016/j.scitotenv.2018.11.298.

Lai, H.-J., Ying, G.-G., Ma, Y.-B., Chen, Z.-F., Chen, F. & Liu, Y.-S. (2013) 'Occurrence and dissipation of benzotriazoles and benzotriazole ultraviolet stabilizers in biosolid-amended soils', *Environmental Chemistry*, first published 24 December 2013. https://doi.org/10.1002/etc.2498.

Langford, K.H., Reid, M.J., Fjeld, E., Øxnevad, S., & Thomas, K.V. (2015) 'Environmental occurrence and risk of organic UV filters and stabilizers in multiple matrices in Norway', *Environment International*, 80, pp. 1–7. https://doi.org/10.1016/j.envint.2015.03.012.

Liu, R., Ruan, T., Wang, T., Song, S., Guo, F., & Jiang, G. (2014). Determination of nine benzotriazole UV stabilizers in environmental water samples by automated on-line solid phase extraction coupled with high-performance liquid chromatography–tandem mass spectrometry. *Talanta*, 120, 158-166. https://doi.org/10.1016/j.talanta.2013.10.041.

Liu, X., Pei, X., Li, J., Wei, Y., Sun, H., Wu, Z., Wang, S., Chen, J., Lin, Z., & Yao, Z. (2024) 'Occurrence, spatial distribution, and ecological risk of benzotriazole UV stabilizers (BUVs) in sediments from Bohai Sea of China', *Environmental Research*, 260, 119730. https://doi.org/10.1016/j.envres.2024.119730.

Mao, W., Jin, H., Guo, R., & Mao, K. (2024) 'Presence of benzotriazole ultraviolet stabilizers in human urine', *Environmental Toxicology and Chemistry*. Available online 3 July 2024.

MHLW (2020). Positive list system for food utensils, containers and packaging, schedule 1 table 2 of the reference list (website in Japanese).

Mikkelsen, S. H., Lassen, C., Warming, M., Hansen, E., Brinch, A., Brooke, D., Crookes, M., Nielsen, E., & Bredsdorf, L. (2015). Survey and health assessment of UV filters. In The Danish Environm. Protection Agency (Vol. 142, Issue 142).

Montesdeoca-Esponda, S., Torres-Padrón, M.E., Novák, M., Krchová, L., Sosa-Ferrera, Z., & Santana-Rodríguez, J.J. (2020) 'Occurrence of benzotriazole UV stabilizers in coastal fishes', *Journal of Environmental Management*, 269, 110805. https://doi.org/10.1016/j.jenvman.2020.110805.

Montesdeoca-Esponda, S., Torres-Padrón, M.E., Sosa-Ferrera, Z., & Santana-Rodríguez, J.J. (2021) 'Fate and distribution of benzotriazole UV filters and stabilizers in environmental compartments from Gran Canaria Island (Spain): A comparison study', *Science of The Total Environment*, 756, 144086. https://doi.org/10.1016/j.scitotenv.2020.144086.

MPI Chemie BV (2022). UV-3035. Accessed March 23, 2022, from https://mpi.eu/chemie/products/uv-absorbers/uv-3035-cas-5232-99-5/.

Nakajima, R., Ikuta, T., Oguri, K., & Ritchie, H. (2023) 'Occurrence of polybrominated diphenyl ethers and benzotriazole UV stabilizers in the hadal amphipod *Hirondellea gigas*', *iScience*, 26(7), 107054. https://doi.org/10.1016/j.isci.2023.107054.

NHFPC (2016). National Food Safety Standard: Standard for the Use of Additives in Food Contact Materials and Articles. GB 9685-2016.

NICNAS (2017). Phenolic benzotriazoles: Environment tier II assessment.

OECD. 2001. Extended producer responsibility – A guidance manual for governments.

Patil, R.S., Thomas, J., Patil, M. & John, J., 2023. *To shed light on the UV curable coating technology: current state of the art and perspectives*. Journal of Composites Science, 7(12), p.513. Available at: https://doi.org/10.3390/jcs7120513.

Rani, M., Shim, W. J., Han, G. M., Jang, M., Song, Y. K., & Hong, S. H. (2017). Benzotriazole-type ultraviolet stabilizers and antioxidants in plastic marine debris and their new products. Science of the Total Environment, 579, 745–754. https://doi.org/10.1016/j.scitotenv.2016.11.033.

Raval, H.G., Baldania, S.L. & Shah, D.A., n.d. *Practical in Organic Chemistry*. Nirav Prakashan, p.303.

Sarah, M. E., Cristina, Á. R., María, E. T. P., & José, J. S.-R. (2019). Monitoring and environmental risk assessment of benzotriazole UV stabilizers in the sewage and coastal environment of Gran Canaria (Canary Islands, Spain). *Journal of Environmental Management*, 233, 567-575. https://doi.org/10.1016/j.jenvman.2018.12.079.

Schaller, C., Rogez, D., & Braig, A. (2008). Hydroxyphenyl-s-triazines: Advanced multipurpose UV-absorbers for coatings. *Journal of Coatings Technology and Research*, 5(1), 25–31. https://doi.org/10.1007/s11998-007-9025-0.

SPIN (2022). SPIN substances in preparations in nordic countries. Accessed March 9, 2022, from http://www.spin2000.net/spinmyphp/.

Struk-Sokołowska, J., Faszczewska, A., Kotowska, U., & Mielcarek, A. (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*, 914, 169813. https://doi.org/10.1016/j.scitotenv.2023.169813.

Swiss Federal Department of Home Affairs (2020). Ordinance of the FDHA on materials and articles intended to come into contact with foodstuffs (SR 817.023.21), Annex 10. https://www.fedlex.admin.ch/eli/oc/2022/564/de/annexes.

UNEP (2007/2019). Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants (original version 2007 last revised 2019). Available at: http://chm.pops.int/Implementation/BATBEP/BATBEPGuidelinesArticle5/tabid/187/Default.aspx.

UNEP (2009). General guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals (POPs). UNEP/POPS/POPRC.5/10/Add.1.

UNEP (2011). Global Guidance Principles for Life Cycle Assessment Databases - A Basis for Greener Processes and Products. http://www.unep.fr/shared/publications/pdf/DTIx1410xPA-GlobalGuidancePrinciplesforLCA.pdf.

UNEP (2021). Guidance on sampling, screening and analysis of persistent organic pollutants. Secretariat of the Basel, Rotterdam and Stockholm conventions, Geneva. Available at: http://chm.pops.int/Implementation/NationalImplementationPlans/Guidance/tabid/7730/Default.aspx.U NEP (2022a). Report of the Persistent Organic Pollutants Review Committee on the work of its seventeenth meeting: Risk profile for UV-328. UNEP/POPS/POPRC.17/13/Add.3.

UNEP (2022b). Draft risk profile: UV-328. UNEP/POPS/POPRC.17/4.

UNEP (2022c). UV-328. UNEP/POPS/POPRC-18/2.

UNEP (2023). *Risk management evaluation for UV-328*. Persistent Organic Pollutants Review Committee, Eighteenth Meeting, Stockholm Convention. Document UNEP/POPS/POPRC.18/11/Add.2.

UNEP (2024). Guidance on preparing inventories of UV-328. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva.

US Food and Drug Administration (2021). Inventory of Food Contact Substances Listed in 21 CFR. https://www.fda.gov/food/packaging-food-contact-substances-fcs/inventory-food-contact-substances-listed-21-cfr.

US EPA (2018). Chemical Data Reporting. Accessed March 8, 2022, from https://www.epa.gov/chemical-data-reporting/2016-chemical-data-reporting-results.

US EPA (2020). Chemical Data Reporting. Accessed June 21, 2022, from https://www.epa.gov/chemical-data-reporting/access-cdr-data#2020.

Watanabe, Y., Kojima, H., Takeuchi, S., Uramaru, N., Sanoh, S., Sugihara, K., Kitamura, S., & Ohta, S. (2015). Metabolism of UV-filter benzophenone-3 by rat and human liver microsomes and its effect on endocrine-disrupting activity. *Toxicology and Applied Pharmacology*, 282(2), 119–128. https://doi.org/10.1016/j.taap.2014.12.002.

Wang, W., Lee, I.-S., & Oh, J.-E. (2022) ‘Specific-accumulation and trophic transfer of UV filters and stabilizers in marine food web’, *Science of The Total Environment*, 825, 154079. https://doi.org/10.1016/j.scitotenv.2022.154079.

Wick, A., Jacobs, B., Kunkel, U., Heininger, P., & Ternes, T.A. (2016) ‘Benzotriazole UV stabilizers in sediments, suspended particulate matter and fish of German rivers: New insights into occurrence, time trends and persistency’, *Environmental Pollution*, 212, pp. 401–412. https://doi.org/10.1016/j.envpol.2016.01.024.

Yamashita, R., Hiki, N., Kashiwada, F., Takada, H., Mizukawa, K., Hardesty, B.D., Roman, L., Hyrenbach, D., Ryan, P.G., Dilley, B.J., Muñoz-Pérez, J.P., Valle, C.A., Pham, C.K., Frias, J., Nishizawa, B., Takahashi, A., Thiebot, J.-B., Will, A., Kokubun, N., Watanabe, Y.Y., Yamamoto, T., Shiomi, K., Shimabukuro, U., & Watanuki, Y. (2021) ‘Plastic additives and legacy persistent organic pollutants in the preen gland oil of seabirds sampled across the globe’, *Environmental Monitoring and Contaminants Research*, 1, pp. 97–112. Available at: https://www.jstage.jst.go.jp/article/emcr/1/0/1_20210009/_article.

ZDHC (Zero Discharge of Hazardous Chemicals Programme). (2015). Chemical Management System Guidance Manual. https://uploads-ssl.webflow.com/5c4065f2d6b53e08a1b03de7/5db6f0404b859058c4c26b1a_CMS_EN.pdf.

Zhang, D., Liu, C., & Yang, Y. (2016). Determination of UV Absorbers and Light Stabilizers in Food Packing Bags by Magnetic Solid Phase Extraction Followed by High Performance Liquid Chromatography. Chromatographia, 79(1–2), 45–52. https://doi.org/10.1007/s10337-015-2988-6.

Zheng, X., Ren, X.-M., Zhao, L., & Guo, L.-H. (2020). Binding and activation of estrogen related receptor γ as possible molecular initiating events of hydroxylated benzophenones endocrine disruption toxicity. *Environmental Pollution*, 263, 114656. https://doi.org/10.1016/j.envpol.2020.114656.