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

August 2024

STOCKHOLM CONVENTION

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Abbreviations and acronyms

ABS	Acrylonitrile butadiene styrene
AOPs	Advanced oxidation processes
BAT	Best available techniques
BEP	Best environmental practices
CBI	Confidential Business Information
CEMS	Continuous emission monitoring systems
EIA	Environmental impact assessments
EMAS	Management and Audit Scheme
EMS	Environmental Management System
GC-MS	Gas chromatography-mass spectrometry
HALS	Hindered amine light stabilizers
HDPE	High-density polyethylene
HEPA	High-efficiency particulate air
HPVC	High production volume chemical
IDIS	International Dismantling Information System
IMDS	International material data system
JRC	Joint Research Centre
LCA	Life cycle assessment
LCD	Liquid crystal devices
LCM	Life cycle management
LC-MS	Liquid chromatography-mass spectrometry
LDPE	Low-density polyethylene
LED	Light-emitting diodes
LEV	Local Exhaust Ventilation
LOD	Limit of detection
MBRs	Membrane bioreactors
PC	Polycarbonate
PET	Polyethylene terephthalate
PEWS	Prioritization and Early Warning System
POPs	Persistent organic pollutants
POPRC	Persistent Organic Pollutants Review Committee
PP	Polypropylene
PPE	Personal Protective Equipment
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl chloride
R&D	Research and development
RO	Reverse osmosis
SPE	Solid-phase extraction
SVHC	Substances of very high concern
TAC	Triacetyl cellulose
TPE	Thermoplastic elastomer
TSCA	Toxic Substances Control Act
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

Executive Summary

UV-328 is a phenolic benzotriazole used as an ultraviolet (UV) absorber to protect various surfaces from discoloration and weathering. It is persistent, bioaccumulative, and has significant adverse effects on human health and the environment.

UV-328 is produced in large quantities globally, with a production volume exceeding 1,000 tonnes per annum. It is used extensively in various applications, including automotive parts, industrial coatings, and mechanical separators in blood collection tubes.

The application of best available techniques (BAT) and best environmental practices (BEP) are detailed for various applications 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.

UV-328 waste should be managed in an environmentally sound manner in accordance with Article 6 of the Stockholm Convention and the Basel Convention General and specific technical guidelines. Reuse and recycling of POPs-containing wastes and stockpiles is not allowed under the Convention, unless specified through an exemption. The destruction or irreversible transformation of the UV-328 waste and to avoid 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.

Alternatives for the substitution of UV-328 are widely available, i.e., other phenolic benzotriazoles, benzophenones, hindered amine light stabilizers (HALS), oxalanilides and cyanoacrylates. Safer alternatives for the most relevant applications of UV-328 seem to be technically feasible and accessible. Information on specific uses, where chemical or non-chemical alternatives are not 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 EU'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

1. In May 2020, Switzerland submitted a proposal to list UV-328 in Annex A to the 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 in Annex D.

2. In May 2023, by decision SC-11/11, The Conference of the Parties considered the risk profile and the risk management evaluation for UV-328 and decided to amend part I of Annex A to the Stockholm Convention on Persistent Organic Pollutants (POPs) to list UV-328 with specific exemptions.

1.1. Purpose

3. The concept of Best Available Techniques (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).

4. 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).

5. This guidance document has been developed to guide 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 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

6. 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.

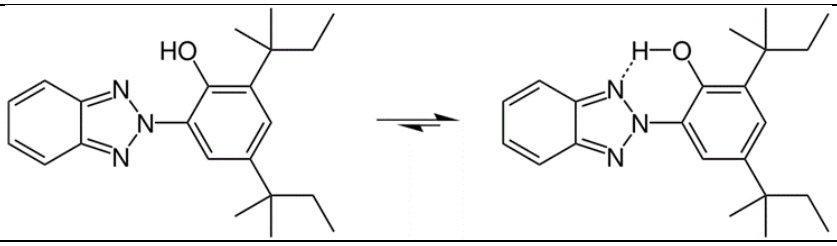
7. UV-328 is a substance that does not occur naturally in the environment, but has been detected in various environmental compartments, biota and humans all over the world. It is considered to be

persistent and bioaccumulative, with significant adverse human health and/or environmental effects (UNEP/POPS/POPRC.17/13/Add.3).

Table 1. Names and registration 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% (w/w)
Structural formulas (left: open form; right: closed form)	

2. Production and use

2.1. Production

8. 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 OECD Existing Chemicals Database, UV-328 is designated as a high production volume chemical (HPVC), with production > 1000 tonnes per annum (t/a) (UNEP/POPS/POPRC.17/4). Worldwide, there are 77 suppliers of UV-328 (ECHA, 2020).

9. In the 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).

10. 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.

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

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

13. 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.

14. In the 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).

15. 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).

16. In the US, 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 (CBI) (2 companies/company sites) (US EPA, 2018).

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

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

19. 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).

20. In summary, UV-328 is produced in large quantities worldwide with a 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.

21. In June 2023, by decision SC-11/11, the Conference of the Parties to the Stockholm Convention listed UV-328 into Annex A of the Convention. 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

22. 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. Use

23. 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 (ABS) 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).

24. In the EU, suppliers of articles containing UV-328 in a concentration above 0.1% w/w need to submit information on these articles from 5 January 2021 to the SCIP database (Substances of 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 (≥ 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 (LED) (≥ 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).

25. 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).

26. Based on the 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.

27. 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 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 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).

28. 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 food contact plastics additives

29. 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).

In automobile

30. 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

31. 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).

32. 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 (LDPE) 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).

33. Brosché et al. (2021) analyzed 24 samples of plastic pellets sold as high-density polyethylene (HDPE) 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 samples (71 % of samples) 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 (LOD) was 0.03 µg/kg (Brosché et al., 2021).

In textiles

34. For the use of UV-328 in textiles, the typical loading of UV-328 is not known. 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.

35. 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 (PU) 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.

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

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

37. 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 mass 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.

38. From the available data, the BAT and BEP for the use of UV-328 on parts of motor vehicles are as follows:

(a) Pre-Production and Raw Material Handling

- **Secure Storage:** Store UV stabilizer raw materials in climate-controlled conditions to prevent degradation and use containers that are resistant to UV light and physical damage.

- **Transfer Systems:** Employ closed-loop conveyance systems for transferring raw materials to the mixer, minimizing exposure to the environment and reducing the risk of spillage.

- **Inventory Management:** Utilize inventory management software to track raw material use and ensure optimal stock levels, reducing the potential for over-ordering and waste.

(b) Production Process

- **Process Optimization**: Use process optimization software to continually assess the efficiency of additive use, ensuring that the smallest effective quantity is utilized.

- **Automated Dosing and Dispersion Systems:** Use advanced, automated dosing systems that ensure precise measurements and uniform dispersion of additives in automotive coatings or parts, minimizing excess use and waste. Reprogram robots in automotive seat and interior manufacturing plants to optimize spray width and improve accuracy.

- **Enclosed Production Environments:** Implement enclosed manufacturing processes that contain any vapors or particulates within the system, greatly reducing occupational exposure and environmental release.

(c) Post-Production and Environmental Safety

- **Spillage Control:** Develop a spillage control plan, including spill kits at handling stations, and train personnel in spill response techniques to minimize environmental contamination.

- **Extraction Systems:** Install localized extraction systems at points of emission, which directly capture fumes or particulates at the source, before they disperse into the wider environment.

- **On-site Solvent and Material Recovery:** Set up solvent recovery systems that allow for the condensation and reuse of volatile compounds, reducing the need for fresh solvents and minimizing waste.

- **Emissions Control Technology:** Employ advanced air purification technologies, such as scrubbers and carbon adsorption systems, to capture airborne contaminants and ensure clean air release during production.

- **Integrated 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 [1] on UV-328 waste. 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.

(d) Ongoing Monitoring and Management

- **Employee Engagement:** Foster a culture of environmental responsibility among employees by incentivizing the identification and implementation of waste-reduction ideas. Implementing comprehensive occupational health programs that include exposure monitoring, regular training, and the provision of personal protective equipment.

- **Continuous Monitoring and Control Systems:** Utilize continuous emission monitoring systems (CEMS) and regular environmental auditing to track and manage emissions and ensure compliance with environmental standards.

- **Environmental Impact Assessments:** Conducting thorough environmental impact assessments (EIA) to identify the potential ecological footprint of the manufacturing process and mitigate adverse effects.

- **Lifecycle Impact Reduction:** 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.

[1]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.

- **Environmental Management Systems:** Implement and maintain an Environmental Management System (EMS) compliant with ISO 14001 or equivalent, ensuring continuous improvement in environmental performance.

(e) Regulatory Compliance and Sustainability Practices

- **Green Chemistry:** Prioritize the use of safer, greener chemicals and processes that minimize or eliminate the use and generation of hazardous substances in the design, manufacture, and application of automotive parts.

- **Regulatory Alignment:** Ensure all processes are in compliance with the most stringent regulatory requirements across all jurisdictions where the products are manufactured and sold, adapting processes as regulations evolve.

3.2. BAT and BEP for the use of UV-328 on industrial coating

39. UV-328 enhances 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:

40. 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.

41. The BAT and BEP for the use of UV-328 on industrial coating are as follows:

(a) Material Sourcing and Pre-Production

- **Sustainable Supplier Selection**

  - Evaluate suppliers based on their environmental certifications (e.g., ISO 14001) and sustainability practices. Prioritize those using green chemistry principles in their production.

  - Conduct audits to ensure suppliers' adherence to environmental and safety standards.

- **Material Storage**

  - Store chemical stabilizers 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.

(b) Production Process

- **Formulation Optimization**

  - 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.

- **Energy Efficiency in Manufacturing**

  - 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.

- **Advanced Application Techniques**

  - Employ precision application equipment, such as automated dosing systems and robotic arms, to ensure accurate and efficient application of stabilizers in coatings.

  - Regular maintenance and calibration of equipment to prevent leaks and inefficiencies.

(c) Post-Production and Waste Management

- **Emission Reduction**

  - 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.

- **Solvent Recovery and Recycling**

  - Use solvent recovery units to capture and recycle solvents from the coating application process.

  - Implement closed-loop systems for the recovery and reuse of process water, minimizing wastewater generation.

  - 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.

- **Waste Management**

  - Ensure the environmentally sound disposal of UV-328 wastes according to the Basel Convention General and specific technical guidelines on UV-328 waste. 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. Partner with certified waste management companies specializing in the management of POP waste.

(d) Continuous Improvement and Regulatory Compliance

- **Workforce Training and Engagement**

  - Conduct regular training sessions on environmental best practices and safe handling of chemicals for all employees.

  - Establish a reporting mechanism for employees to suggest improvements or report potential environmental issues.

- **Compliance Monitoring**

  - Implement continuous monitoring systems to track emissions, waste generation, and energy use.

  - Stay informed of regulatory changes and update operational practices to maintain compliance with environmental laws and standards.

- **Lifecycle and Impact Assessments**

  - LCA to evaluate the environmental impact of products from raw materials to end-of-life.

  - Use the findings from LCAs to inform product design, material selection, and recycling strategies.

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

42. 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 percent by weight of the formulation[2].

43. Following is the BAT and BEP for the use of UV-328 on mechanical separators in blood collection tubes:

(a) Raw Material Acquisition and Storage

- **Sustainable Sourcing**: Partner with suppliers who adhere to sustainable practices in the production and supply of raw materials, including UV-328. Certification through

[2] REACH – Applications for authorisation AFA017-01 – UV-328 - Health and Safety Executive - Citizen Space (hse.gov.uk)

recognized environmental standards (e.g., ISO 14001 for environmental management) should be a prerequisite for supplier selection.

- **Safe Storage Practices**: Utilize smart monitoring systems in storage areas for UV-328 and TPE polymers that can continuously monitor and adjust temperature and humidity levels to optimal conditions, reducing the risk of degradation or hazardous reactions. Containers should be made from materials that do not react with UV-328 and are labeled with all hazard information.

- **Material Handling System**s: Design material handling systems to minimize dust 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.

(b) Manufacturing Process

- **Compounding and Extrusion Process**

  - **Automated Dosing for Accuracy:** Implement automated dosing systems with real-time monitoring to precisely control the amount of UV-328 added to the TPE mixture, ensuring uniform distribution while minimizing waste.

  - **Energy Recovery Systems:** In the extrusion process, utilize energy recovery systems to capture and reuse heat generated, reducing overall energy consumption.

  - **Energy-Efficient Machinery:** 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 can capture and reuse heat generated during the manufacturing process.

  - **Closed-Loop Water Systems**: Implement closed-loop cooling systems for machinery, which reduce water consumption by recycling and reusing water within the production facility.

- **Molding and Curing**

  - **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.

  - **Curing Area Ventilation:** Equip curing areas with Local Exhaust Ventilation (LEV) systems specifically designed to capture any off-gassed substances, ensuring they are treated before being released into the atmosphere.

(c) Quality Control

- **Quality Control Systems:** Use advanced quality control systems to monitor product quality throughout the production process, reducing the need for rework and the associated additional resource consumption.

(d) Emissions and Waste Management

- **Solvent Recovery and Reuse:** For processes that require solvents, employ solvent recovery units to capture and recycle solvents that do not contain UV-328 from the exhaust streams, significantly reducing solvent consumption and emissions.

- **VOC Reduction Systems:** In processes where volatile organic compounds (VOCs) might be released (e.g., during heating), install VOC abatement systems like carbon adsorption units or thermal oxidizers that can effectively remove or neutralize VOCs before air is released into the environment.

- **Solid Waste Reduction:** Initiate a zero-waste policy focusing on the reduction of solid waste through material efficiency, recycling of scrap material that do not contain UV-328, and the conversion of waste into energy where feasible.

- **Treatment of Wastewater:** Implement advanced wastewater treatment facilities capable of removing contaminants, including any residual UV-328, from process water before discharge.

(e) Workplace Safety and Health

- **Occupational Exposure Limits:** Establish strict occupational exposure limits for UV-328 and monitor air quality in the workplace to ensure compliance, protecting worker health.

- **Safety Training Programs:** Develop comprehensive safety training programs that cover the safe handling of chemicals, emergency response, and the use of personal protective equipment.

(f) Continuous Monitoring and Compliance

- **Environmental Management Systems (EMS):** Develop and maintain an EMS that complies with ISO 14001 standards, focusing on continuous improvement in environmental performance across all areas of the TPE production process.

- **Regulatory Compliance:** Stay updated on local and international regulations related to chemical use and waste management. Regular audits should be conducted to ensure compliance with laws and guidelines, such as REACH in Europe and the Toxic Substances Control Act (TSCA) in the United States.

- **Product Lifecycle Assessment (LCA):** Conduct LCAs for products containing UV-328 to identify potential environmental impacts throughout their lifecycle, from raw material extraction to end-of-life disposal. Use the findings to inform design and process improvements aimed at minimizing environmental impact.

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

44. 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.

45. In the industrial application of UV-328 to TAC film for LCD polarizers, the process commences with the preparation of a TAC resin solution. UV-328 is incorporated into this solution as a UV stabilizer to counteract degradation caused by ultraviolet radiation. The resulting solution is then uniformly applied onto a smooth carrier using a precision-controlled casting machine, ensuring precise film thickness and uniformity. After casting, the film undergoes solvent evaporation in controlled temperature environments, facilitating the solidification of the TAC film. Subsequently, polarization treatment modifies its molecular structure through stretching and application of polarizing materials to impart essential directional properties required for LCD functionality. Following polarization, the

film is precisely cut to specified dimensions and assembled alongside other critical LCD components such as liquid crystal layers and glass substrates.

46. According to the description of the manufacturing process mentioned above, the BAT and BEP for the use of UV-328 on TAC film in polarizers are as follows:

(a) Material Handling and Preparation

- **Automated Dosing and Precision Compounding:** Utilize automated dosing systems for accurate addition of UV-328, minimizing excess. Employ advanced compounding techniques to ensure even distribution of UV-328 in TAC solutions.

- **Secure and Sustainable Storage:** Store UV-328 under optimal conditions using smart containers equipped with sensors for real-time monitoring, ensuring material integrity and reducing waste.

- **Sealed Transfer Systems:** Utilize fully enclosed, automated systems for transferring chemicals to minimize airborne emissions and spills. Incorporate leak detection technologies to identify and address leaks promptly.

(b) Manufacturing Process

- **Closed-Loop Systems and Advanced Filtration:** Implement closed-loop processes in mixing and application stages to reduce exposure and environmental release. Equip these systems with high-efficiency particulate air (HEPA) and activated carbon filters to capture particulates and VOCs.

- **Dust Suppression Techniques:** In powder handling areas, apply dust suppression methods, such as misting, to prevent the dispersal of particulate matter.

- **Low-VOC Solvents:** Where solvents are required, select those with low volatile organic compound (VOC) content to reduce airborne emissions.

- **Catalytic Oxidizers:** Install catalytic oxidizers to treat exhaust streams containing VOCs, transforming them into harmless water vapor and CO_2 through a chemical reaction facilitated by a catalyst.

- **Ultraviolet (UV) Photolysis:** 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.

(c) Quality Assurance

- **Quality Control and Lifecycle Management:** Incorporate rigorous quality control measures to minimize the need for rework. Analyze the environmental impacts of TAC films with lifecycle assessments to identify areas for improvement.

(d) Emission Monitoring and Control

- **Real-time Emission Monitoring:** Deploy continuous CEMS to track and report emissions of VOCs, particulate matter, and other pollutants in real-time, ensuring compliance with environmental standards.

- **Destruction technologies:** For waste gases not suitable for catalytic oxidation or UV photolysis, thermal incineration at high temperatures may be used to break down toxic

compounds. Refer to the Basel Convention general technical guidelines on POPs wastes for appropriate technologies for the environmentally sound destruction and irreversible transformation of UV-328.

- **Effluent Treatment**: Install advanced wastewater treatment systems capable of effectively removing UV-328 and other contaminants from process effluents before discharge. Employ appropriate treatment technologies to treat wastewater containing UV-328 to meet stringent discharge standards.

(e) Worker Safety and Environmental Protection

- **Comprehensive Safety Programs and Environmental Monitoring:** Provide ongoing training on safe handling of materials and emergency response. Monitor workplace and environmental air quality to ensure compliance with safety standards.

- **Personal Protective Equipment (PPE):** Provide comprehensive PPE to workers handling hazardous materials, including respirators, gloves, and protective clothing.

- **Ventilation and Air Quality:** Ensure work areas are well-ventilated with clean air recirculation systems.

- **Supplier and Stakeholder Engagement:** Engage with suppliers to ensure they adhere to sustainable practices. Maintain open communication with stakeholders to promote transparency in environmental performance.

(f) Continuous Improvement and Regulatory Compliance

- **Innovation and Sustainable Alternatives Exploration:** Invest in research and development (R&D) to find safer and more sustainable alternatives to UV-328. Regularly review and update processes in response to technological advancements and regulatory changes.

- **Documentation and Compliance:** Maintain thorough documentation of all processes, waste management practices, and compliance efforts with local and international regulations, such as REACH.

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

47. In the industrial process of applying UV-328 to photographic paper, UV-328 serves as a photostabilizer to enhance the paper's lightfastness and durability. The process begins with the preparation of a base paper, typically made from pulp, which undergoes refining, forming, and drying to achieve a smooth surface with proper ink absorption properties. UV-328 is then incorporated into coatings and applied onto the surface of the base paper using techniques such as gravure, roll-to-roll coating, or spraying to ensure uniform coverage. After coating, the paper undergoes drying and curing to remove solvents and solidify the coating layer, often achieved through methods like hot air drying, infrared radiation, or UV curing. Surface treatments such as resin coating, calendering, or matte finishing may follow to improve glossiness and texture. Subsequently, the paper is cut to the desired size and packaged for storage and transportation. Throughout the process, quality control measures are implemented to ensure compliance with specifications, including physical and chemical testing of coatings and paper properties, as well as visual inspection of the final photographic paper product.

48. The BAT and BEP for the use of UV-328 on photographic paper are as follows:

(a) Material Preparation and Handling

- **Secure Containment:** Store UV-328 in containers that are resistant to UV degradation and physical damage, within climate-controlled environments to prevent degradation. Implement an automated inventory management system to track and optimize the use of UV-328, reducing excess and waste.

(b) Manufacturing Process Integration

- **Precision Dosing Technology:** Utilize precision dosing technology to incorporate the exact amount of UV-328 required into the coating solution for photographic paper, minimizing waste and ensuring consistent product quality.

- **Encapsulation Techniques:** Explore encapsulation techniques for UV-328 to reduce its potential volatility during the application process, thereby minimizing worker exposure and environmental release.

(c) Coating Application

- **Closed-Loop Application Systems: E**mploy closed-loop systems with advanced ventilation for the application of UV-328-infused coatings, ensuring minimal emissions of volatile organic compounds (VOCs) and particulates.

- **High-Efficiency Particulate Air (HEPA) Filtration:** Install HEPA filtration systems to capture fine particulates from the air, significantly reducing airborne transmission of any particulates related to UV-328.

(d) Pollution Control Technologies

- **Thermal Oxidizers:** Implement thermal oxidizers to treat exhaust streams containing VOCs from the coating process, converting them into water vapor and carbon dioxide through combustion at high temperatures.

- **Solvent Recovery Systems:** In processes where solvents are used for cleaning or other purposes, use solvent recovery systems to condense and reuse solvents, minimizing solvent waste and emissions.

(e) Waste Management and Minimization

- **Waste Segregation and Recycling Programs:** Segregate waste materials generated during the manufacturing process, especially those containing UV-328, ensuring proper disposal according to Basel Convention technical guidelines.

(f) Energy Efficiency and Conservation

- **Renewable Energy Sources:** 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.

(g) Worker Safety and Health

- **Comprehensive Safety Protocols:** Develop and implement comprehensive safety protocols for handling UV-328, including training on the use of PPE and emergency response procedures.

(h) Continuous Monitoring and Improvement

- **Emissions Monitoring Systems:** Deploy CEMS to track emissions of VOCs and particulates, ensuring compliance with environmental standards and facilitating prompt corrective actions.

- **Environmental Impact Assessments (EIA):** Conduct regular 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.

3.6. BAT and BEP for the use of UV-328 on stationary industrial machines

49. 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.

50. 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.

51. The BAT and BEP for the use of UV-328 on stationary industrial machines are as follows:

(a) Chemical Management and Application

- **Automated Precision Dosing:** Employ computer-controlled systems for the exact measurement and addition of UV-328 to prevent overuse and minimize waste. Such systems should ensure a homogeneous mixture in coatings or materials.

- **Enclosed Processing:** Use fully enclosed systems for mixing and applying UV-328-containing materials, equipped with local exhaust ventilation to capture any released VOCs or particulates, minimizing worker exposure and environmental release.

(b) Pollution Control Technologies

- **VOC Abatement: I**nstall thermal oxidizers or catalytic converters in exhaust streams to break down VOCs into CO_2 and water, significantly reducing harmful emissions.

- **Solvent Recovery Systems:** Implement solvent recovery technologies, such as distillation columns, for recondensing and reusing solvents from the coating processes, reducing the demand for new solvents and decreasing VOC emissions.

- **Particulate Filtration:** Equip facilities with HEPA filters in air extraction systems to capture fine particulates from the air, ensuring they are not released into the environment.

(c) Waste Management

- **Handling:** 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. Ensure the environmentally sound disposal of UV-328 wastes according to the Basel Convention General and specific technical guidelines on UV-328 waste[3].

- **Material Recycling:** 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.

(d) Worker Safety

- **Safety Training:** Conduct comprehensive training sessions on the safe handling of UV-328 and associated chemicals, including emergency response protocols and the correct use of PPE.

- **Health Monitoring:** Establish a health monitoring program for employees who are potentially exposed to UV-328, ensuring any health impacts are promptly identified and addressed.

(e) Environmental Compliance and Monitoring

- **Continuous Emission Monitoring:** Utilize CEMS to continuously monitor air emissions for compliance with environmental standards. Adjust processes as needed based on real-time data.

- **Wastewater Treatment Monitoring:** Ensure that advanced wastewater treatment processes capable of effectively removing contaminants, including traces of UV-328, before discharge are in place, adhering to water quality standards.

(f) Continuous Improvement and Engagement

- **Process Optimization:** Regularly review and optimize manufacturing processes to enhance efficiency, reduce chemical use, and minimize waste and emissions.

- **Stakeholder Communication:** Maintain transparent communication with regulatory bodies, employees, and the local community about environmental management practices and performance.

3.7. BAT and BEP for the use of UV-328 on liquid crystal displays

52. UV-328 is a commonly used UV stabilizer in the production of liquid crystal displays (LCDs), particularly in the manufacturing of polarizing films. In the industrial operation process of applying UV-328 in LCD production, UV-328 is initially prepared into a solution by dissolving it in a suitable solvent such as toluene or ethyl acetate. This solution is then uniformly applied onto substrates, typically TAC

[3] General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (UNEP/CHW.16/6/Add.1)

films, using methods like spin coating or roll-to-roll coating. Following coating, the substrates undergo drying and curing processes to remove solvents and solidify the UV-328 layer, ensuring adhesion and stability. Depending on the specific formulation and requirements, the drying process may involve techniques such as hot air drying, infrared drying, or UV curing to accelerate the solvent evaporation and solidification of UV-328. The UV-328-coated substrate serves as a component in the assembly of polarizing films, which are essential for controlling the passage of light through the LCD panel. These UV-328-coated substrates, components for polarizing films, are then integrated into LCD assembly lines, contributing to the optical properties and durability of the final display. Rigorous quality checks are conducted throughout the process to ensure coating uniformity and UV absorption properties meet specifications.

53. The BAT and BEP for the use of UV-328 on liquid crystal displays are as follows:

(a) Material Preparation and Handling

- **Micro-encapsulation of UV-328:** Employ micro-encapsulation techniques to bind UV-328 in a polymer matrix, reducing volatility and potential for worker exposure during handling.

- **Automated Material Transfer:** Use automated, vacuum-sealed material transfer systems to move UV-328 from storage to the production area, minimizing airborne particles and contact.

(b) Coating Application

- **Precision Coating Techniques:** 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.

- **VOC Abatement Systems:** Install VOC abatement systems, such as thermal oxidizers or catalytic converters, to treat exhaust gases from the coating process, breaking down VOCs into less harmful substances.

(c) Curing Process

- **UV Curing Technology:** Utilize UV curing technology, which can be more energy-efficient and emit fewer VOCs compared to traditional thermal curing methods.

- **Optimized Curing Chambers:** Design curing chambers with enhanced airflow management and afterburners to capture and decompose any residual VOCs from the curing process.

(d) Waste and Wastewater Management

- **Solvent Recovery Systems:** For processes that use solvents in the coating or cleaning phases, implement solvent recovery and distillation units to recycle solvents not containing UV-328 for reuse.

- **Advanced Wastewater Treatment:** Apply appropriate technologies, ensuring the effective removal or destruction of any residual UV-328 or other hazardous chemicals.

(e) End-of-Pipe Pollution Control

- **High-Efficiency Particulate Air (HEPA) Filters:** Equip ventilation systems with HEPA filters to capture fine particulates emitted during the production process.

- **Activated Carbon Adsorption:** Use activated carbon beds to adsorb and remove chemical vapors from exhaust streams, preventing their release into the environment.

(f) Monitoring and Continuous Improvement

- **Real-Time Monitoring Systems:** Install continuous CEMS and real-time water quality monitoring systems to track the effectiveness of pollution control measures and ensure compliance with environmental standards.

- **Process Optimization Software:** Utilize advanced software tools for ongoing process optimization, reducing the need for hazardous chemicals and minimizing waste production.

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

4.1. Environmental Management Systems (EMS)

54. 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).

55. 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.

56. 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 (EMAS).

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

4.2. Life cycle management

58. 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 (ECCC and Health Canada, 2016). 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.

59. 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[4] 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.

4.3. Producer responsibility

60. The Stockholm Convention's BAT/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 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.

61. Producers' and other stakeholders' responsibilities have been established through initiatives such as the EU's integrated product policy;[5] its thematic strategy on the prevention and recycling of waste[6] and associated framework directives;[7] 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.

62. UV328-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]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

[5] Green Business - European Commission (europa.eu)

[6] Waste and recycling - European Commission (europa.eu)

[7] Waste Framework Directive - European Commission (europa.eu)

4.4. Alternatives

63. Based on the POPRC guidance on alternatives and substitutes, 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).

64. 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). When UV-328 is replaced with other phenolic benzotriazoles, it should be noted that other substances of this chemical class also reveal hazardous properties and were added to the REACH Authorisation List (ECHA, 2020). This includes UV-320, UV 327 and UV-350 (Annex F, UK, 2022; Khare et al., 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).[8]
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-326 (2-*tert*-butyl-6-(5-chloro-2*H*-benzotriazol-2-yl)-4-methylphenol); CAS No. 3896-11-5	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 2023to identify the substance as SVHC due to its vPvB properties.
UV-329 (2-(2*H*-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol); CAS No. 3147-75-9	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 2023to 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.[9]

65. 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.

[8] 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).

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

66. 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).

67. 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.

68. 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).

69. 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).

70. 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.

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

Identification and monitoring of UV-328 in products and article

71. 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.

Identification and monitoring of UV-328 on the environment

72. The environmental monitoring of UV-328 involves assessing its presence in soil, water bodies, air, and wildlife. Given its potential for long-range environmental migration, it is important to track its distribution and concentration in the environment. The detection methods for environmental samples

are similar to those used in product analysis and may include solid-phase extraction (SPE) followed by chromatographic techniques coupled with mass spectrometry for sensitive and accurate analysis. The determination of UV-328 in different environmental water matrices, including river water, wastewater influent and effluent, has been investigated by automated on-line solid-phase extraction coupled with a high-performance liquid chromatography-tandem mass spectrometry system (Sarah et al, 2019; Liu et al, 2014). 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 (PEWS) screening, in June 2021 (Annex F, UK, 2022).

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